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TWELVE

LECTURES

ON

COMPARATIVE PHYSIOLOGY,

DELIVERED BEFORE

THE LOWELL INSTITUTE, IN BOSTON,

JANUARY AND FEBRUARY, 1849,

BY

JEFFRIES WYMAN, M. D.

PHONOGRAPHIC REPORT BY JAMES W. STONE, M. D.

ORIGINALLY REPORTED AND PUBLISHED IN THE BOSTON DAILY EVENING TRAVELLER.

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PROF. WYMAN'S

LECTURES ON COMPARATIVE PHYSIOLOGY.

LECTURE I.

The various races of the great series of beings of which the organic world is composed, may be studied in two different ways, and with two different objects in view. They may be examined in a state of inactivity—as dead bodies—with reference to their purely physical conditions. By the aid of the knife, they may be separated into the various organs of which they are made up. By the aid of the microscope, these organs may be resolved into the different tissues of which they are composed. And if the analysis be carried still further, by the aid of Chemistry, the ultimate elements of which they consist may be ascertained.

The knowledge thus obtained, constitutes the science of Anatomy. But however perfectly these investigations may be pursued; however skilfully the Anatomist may dissect; however nicely the Microscopist may observe; however accurately the Chemist may analyze—they, in the end, give us but an imperfect idea of the objects for which animal structures were created. To obtain a more perfect knowledge, they must be examined in a state of activity, during life. For the researches of the Anatomist will never demonstrate to us that a seed was intended to produce a perfect, organized being, or that muscular fibre was intended to contract, or that a nerve was intended to carry its peculiar influence to and from the nervous centres.

In examining organized beings, during life, the various phenomena which they manifest must be observed. The different processes, of which they are the seat, must be investigated, and, if possible, the laws according to which these processes take place must be determined. The knowledge thus obtained constitutes the science of Physiology. Thus we have this broad distinction between Anatomy and Physiology. Anatomy makes us acquainted with the different structures, their position, composition, and their physical relations; while Physiology, on the other hand, makes us acquainted with the uses to which these different parts are subservient. Anatomy makes known to us the means; Physiology, the ends. To illustrate this distinction, I will not detain you longer than to cite a single illustration. Suppose that we have for examination, a muscle. Anatomically considered, we should find a muscle to have a certain position in the body; to have a certain form; to be made up of fibres of a definite size and shape, and to be attached to certain parts. But the uses of it, Anatomy would never teach. To learn this, we must examine it while in action—during life. Then, we not only find that it has the power of contraction, but may go still farther, and learn the use to which that contraction is subservient. Anatomy stops where Physiology begins. And yet, though quite distinct, they are obviously not to be separated from each other. To attempt to understand the animal kingdom, anatomically, without an acquaintance with Physiology, would be the same as if we should study all the details of a machine, without any idea of the use for which that machine was constructed. And, on the other hand, to study Physiology, without Anatomy, would be like studying the result of the action of the machine, without knowing the means by which they are brought about.

These two sciences, Physiology and Anatomy, take cognizance of all organized beings, and if carried to perfection, would enable us to understand the plan of the organic, living world. These sciences may have, however, a more limited acceptation; they may be applied to a single portion of the organic world; so that we have an

Anatomy and Physiology of plants; an Anatomy and Physiology of animals; and if they be still more limited, we may have the Anatomy and Physiology of a single being, as of the human being.

Comparative Anatomy and Physiology are the sciences which make us acquainted with the anatomical and physiological relations of living beings to each other. But to study the phenomena manifested by a single individual would give us an idea of the organic world, as imperfect as that which an astronomer would obtain of the siderial system, by studying the motions and phenomena of a single planet. It is not true that there exists, strictly speaking, a Physiology as of man, peculiar to a single being. Examine any one organ, and the processes of which it is the seat, in a given animal, then refer to any other being in the animal series, and you will generally find the organ and its processes repeated. Examine the process of respiration, as it exists in man and in those animals nearly allied to him, and it will be seen that so far as regards the essential process, it is one and the same in all, though the manner in which it is carried out may vary to a considerable degree in the different races.

In the present course of lectures, I shall endeavor to explain the more important processes of which the members of the animal kingdom are the seat, and to describe their structures in so far as will enable us to understand the means by which these various processes are effected. As we pass them in review, we shall find that light will be obtained, which enables us to determine more definitely than by any other means, the truth with regard to the uses of various parts of the human body.

By the researches of the Comparative Physiologist, it has been shown that the animal kingdom is subdivided into certain great groups, and that all the members of those groups are constructed on one and the same plan. It has also been shown that, as we pass from one to another of the members of a group, this plan is modified in its details. And it has been still further shown, that this change of plan is always attended with some modification of function. If this be true—that a general plan of structure exists in all the members of a group, and that when this is changed, there is some modification of the processes of which the organ is the seat—then it will be seen that Comparative Anatomy and Physiology are susceptible of practical application.

Suppose you wish to determine the relative importance of any one of the organs of the human body. You have only to look at the animal series, and you will see it in every variety of complications. There is no one part of the economy in which this is better seen than in determining the relative value of the different portions of the nervous system. But, as we shall have many instances of the practical application of Comparative Anatomy and Physiology, I will give but two illustrations. Suppose you wish to show the relative importance of a certain portion of the brain. In comparing the brains of Vertebrated animals, it is found that there are certain parts which are regarded as fundamental and are universally present. Beginning with the fishes, they are the following:—There is one nervous mass, or ganglion, forming the posterior part of the brain, called the Cerebellum; in front of this, a pair of ganglia, the Optic Lobes; in front of these, a second pair, called the Cerebral Lobes, which give off no nerves. Go a little farther, and you find an anterior pair, which give off nerves presiding over the sense of smell. With the exception of a few other parts, but imperfectly known, these are the fundamental portions of the brain. As you pass to the higher forms, you find certain modifications. The nervous masses which we have just described, represent the brain of the Fish, where all the parts are very nearly of the same size. We now pass to the next lowest division of the Vertebrated animals, which is that of Reptiles, where the nervous masses are about the same as in the Fish. The same parts are repeated, but the cerebral lobes are of an increased size.

Passing to the class of Birds, you find that the first part, the Olfactory Lobes, as well as the third, the Optic, are almost removed from sight, in consequence of the second, the Cerebral Lobes being so much larger than in the preceding class; and behind these, we find the fourth, or Cerebellum, as before.

Going a little higher, we pass to the class of Mammals; where we find that the parts which have been so constantly on the increase, have acquired a still greater development; so that we only have exposed to view, when looking at them from above, the Cerebral lobes and the Cerebellum. To go still higher, you find that in looking at the brain, from a similar point of view, in Man, that the Cerebral Lobes are so astonishingly developed as to completely cover all the other parts, even the Cerebellum. These parts, which are constantly on the increase, are in relation to one of the functions of the brain, and that is intelligence. If there is any one portion of the nervous system in which Physiologists are agreed, as being the seat of intelligence, that portion is the one composed of the Cerebral Lobes, which, as you have seen, acquires its maximum of development in Man.

One other thing is necessary for us to consider. In studying the organs, as they exist in the animal series, we are not only enabled to determine the relation of parts to functions, but are enabled to analyze a complex organ, and determine what is essential, and what is superadded to render it more perfect. Let us take as an example, the human Ear. The Ear consists, in Man and in the higher Mammals, of an external portion, then of a tube; within this of a vibrating membrane, stretched across the tympanum; and internally a sac containing fluid, and in which the nerves are distrib-

uted. Then there are three semi-circular canals connected with the sac, and a spiral body called the Cochlea. Now, it remains to be determined, which of these many parts is essential, and which superadded, or only accessory. Suppose that you have all animals arranged in a series; and as you pass from the higher to the lower forms, you will find that one after another of these parts is removed, until, at last, only a single portion remains. In the Whales or Cetaceans you find that the external portion has disappeared, so that the canal merely communicates with the surface, without an external apparatus to collect the sound. Next, in Birds, the outer portion has not only disappeared, but a portion of the tube communicating externally. And in Reptiles, the external ear and canal both disappear, and the vibrating tympanum is on the surface, and the Cochlea is diminished. Pass from animals breathing in the air, to those breathing in the water, and it will be found, in addition to the abovementioned parts, that the vibrating membrane and tympanum, and one of the semicircular canals are no longer present. Passing still lower than this, to animals belonging to the class of Articulata, to the Crustacean, you find that all have disappeared, except the sac containing the fluid, and branches of the nerve. So that we have left, at last, only the essential part of an Ear—that which is absolutely necessary to the reception of sound—the sac with its fluid, with the nerves branching upon its walls.

Physiologists, within the last half century, whose attention has been strongly turned to the determination of the uses of the different parts of the economy, have had recourse to experiments upon living animals. This is now no longer necessary or justifiable; for, as Cuvier has beautifully expressed it, "when you have the animal series, with its ever-varying forms, all arranged before you, you have only to pass your eye along its different members, and you have experiments already prepared to your hand, by Nature herself, who at the same time, points out their various results."

The subject of the present course of lectures, as I have already stated, is intended to take into consideration the uses towhich the organs of the animal series are subservient; and the question arises, at the outset, as to the limit of this series. With regard to the higher forms, there can be no difficulty in distinguishing whether they belong to the Animal or the Vegetable Kingdom. But when you pass from the higher to the lower forms, it will be found that this is far from easy; it will be very perplexing to ascertain where animal life ends, and where vegetable life begins. Turn to the text-books, and you will find that Botanists and Zoologists are constantly claiming certain forms, which have been from time to time alternately transferred from one kingdom to the other. The Sponge is a living being, which has been alternately claimed by the Zoologists and Botanists. It was ascertained that the elements which enter into the structure of animal beings, were oxygen, hydrogen, carbon and nitrogen. Nitrogen was not supposed to enter into the vegetable kingdom. And nitrogen being found in Sponges, was thought to entitle them to a place in the animal kingdom. But soon it was discovered that this ingredient was found to enter into the composition of plants also. So the Sponge was passed to the other side of the line. A distinguished English Physiologist, Dr. Grant, in examining its organization, found that the seeds have the power of moving about, by the aid of vibrating cilia, as is the case with the infusorial Animalcules. Thus the Sponge was transferred to the animal kingdom. Subsequently, it was found that Plants have this same locomotive power, and the Sponge was passed again to the other side of the line, where it will, in all probability, for the future, remain.

If we proceed upon the correct principles of classification, there ought not to be much difficulty in finding the limits of the animal series. Now if its members are arranged in series, at one extreme we shall have the higher forms—at the head of them Man—and at the other, the simplest forms of animal existence.

If, on the other hand, we arrange the Vegetable Kingdom, we find that its members, as they become more simple, approach nearer and nearer to the animal kingdom. Now, how shall we draw the line between the two? To answer this question, we must ascertain first, what are the characters universally present in the organic world.

All animals and vegetables are characterized by the process of *Nutrition*. Minerals, as well as organized beings grow—but they are not *nourished*, but increase in size in quite a different manner. Suppose you have a crystal, which is to grow How is a crystal increased in its size? Simply by the superaddition of new particles on the *outside* of those already existing. But, suppose a living being, of the simplest kind, has an increase of size. It is not by the addition of new matter *upon the surface*, but by interposing the new particles between those which already form its substance.—Nutrition is regarded as one of the common properties of animals and vegetables.

Another property which all organized beings possess, is that of *reproducing their kind*. It has always been a favorite theory with some Physiologists, that certain forms are produced spontaneously; that there existed no being before them which stood in the relation of a parent. At one time, all the animals known as Infusoria, were thought to be formed in this way. But now there is no exception known to the general proposition which I have laid down—that all organized beings possess the property of reproduction. If there be any which are supposed to be exceptions, it is because the whole history of the being is not known. So far as the individual history has been examined, it has been traced back to some pre-existing form. Thus far, we have no distinction

between animals and plants. All are nourished—all have the power of reproducing their kind.

The next most general property is that of *Motion;* and this was supposed for a long time to be characteristic of the animal kingdom. But in examining the germs of many plants, it is found that they are locomotive, and some of them locomotive throughout their whole period of existence. If motion itself, as such, is not characteristic of animals, we have next to ascertain whether there is any difference between the kinds of motion which exist in the organic world. And in doing this, we find the first distinction between Animals and Plants; and in order to understand this more fully, I shall call your attention to these diagrams for the purpose of explaining some motions in the Vegetable Kingdom; and in order to get it more clearly, I would call your attention to a living form which is unquestionably a member of the vegetable kingdom, (Plate I) and that is to a species of Conferva, which is a plant very often seen in the summer, floating on the surface of stagnant water. This plant is made up of cells. Some of these cells contain seeds, from which the whole plant is reproduced.

PLATE I.

Conferva.

It was found some years since, by a German Physiologist, Agardh, that when these germs escaped, they began to move about in circular tracks. In order that there might be no error about these moving particles being the spores of the plant, in order to show they were not animalcules, he watched them still further, and found that after a certain time their form became elongated, that they became attached to the surface, increased in size, formed new cells, and finally reproduced the plant from which they were derived. So that there can be no question but that this is a plant, endowed, during its early period of life, with the power of locomotion. The cause of that locomotion was, until quite recently, wholly unknown. But very lately, Microscopists have discovered the cause.—It was found on examination, that there exists certain filaments (vibrating cilia) which are in incessant motion. These are now known to exist very widely, not only in plants, but in animals.

In another plant called Vaucheria, the cilia, instead of being attached to one end of the spore, as in Conferva, surround the whole circumference.—Thus we have unequivocal evidence of locomotion in the vegetable kingdom, and that motion produced by vibrating cilia. There is no evidence of the existence of will in connection with any of these movements. And there is another proof that they are involuntary, in the fact that they are incessant. All voluntary motions intermit after a certain time.

PLATE II.

Now, I will call your attention to the little animal or organized being (Plate II) seen here. This is the fresh water Polyp, or Hydra. It consists of a cylindrical body, with arms extending around one of the extremities.—This being is also capable of motion, but motion of a different character. Suppose a grain of sand is dropped so as to come in contact with its arms. The moment it is touched the arms are drawn back, and the animal assumes the form you see here, (Plate III). But instead of a grain of sand, suppose an animalcule comes in contact with one of these arms, it does not withdraw the arms, but clasps them around the animal and carries it towards the interior of the body. Here you have a motion entirely different. This motion shows an intelligence, which discriminates—that is to say, avoids one object and seizes another. If you examine any movements of plants, you do not find that anything similar to this exists.

PLATE III.

You may have seen the animals on the sea shore known as the Sea Anemone—an animal proper having a cylindrical body, similar to the Hydra but with more numerous arms. A few particles of sand being dropped on these, they gradually work them out, and throw them off. But if an Animalcule comes in contact with them, it is gradually worked towards the centre, where is situated the mouth. Thus a substance that would harm it, or be useless to it, is rejected, and an animal which can nourish it, is retained. We have here, then, not only motion, but voluntary motion, which is characteristic of animals.

There is still another characteristic which is met with in the animal kingdom, and which voluntary motion presupposes. That is, *Sensation*—not only of recognizing the presence of objects, but of perceiving the different kinds. Of this you have evidence in the motions of the Hydra. If a body which comes in contact with it, is incapable of serving a useful purpose, it is rejected; if it is capable of so doing, then it is appropriated.

There must exist, then, some means of distinguishing between the bodies which are useless and those which are useful: that is sensation.—Sensation and voluntary motion may be regarded as being universally present in this portion of the organic world.

There is still another character to be derived from the manner in which the two groups are nourished. Plants are nourished solely by the absorption of nutritive matter through their outer surface. Suppose you have the leaves, stem and roots of a plant. (These the Professor figured on the black board.) Now, the absorption of the

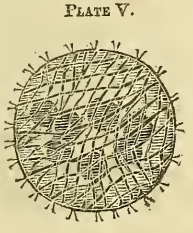
nourishment takes place through the extreme portions of the roots or the leaves. But, in the simplest beings in which sensation and voluntary motion are found, you will find a different method of introducing nutritive matter. The arms of the Hydra (Plate IV) encircle a central opening, which is connected with a sac (*stomach*) in the interior of the animal, into which the nutritive substances are introduced, and then are dissolved; and finally are appropriated to the sustenance of the body. So that this digestive cavity or stomach may be regarded as another characteristic of that group in which voluntary motion exists—that is of the Animal Kingdom.

PLATE IV.

Stomach of a Polyp.

In applying the distinctions which are thus made, we are enabled to assign a true place to many forms which have been regarded as belonging to the animal series by some, and to the vegetable series by others. It is highly probable that a great number of Infusorial Animalcules, so called, will be hereafter transferred to the Vegetable Kingdom, the peculiarities of which, and none others, they have been found, by the most recent investigations, to possess. Here is the figure of a globular being (Plate V) which is known under the name of Volvox. With the aid of its vibrating cilia, it moves incessantly, and in consequence of its moving about so freely in every direction, it has been regarded as belonging to the Animal Kingdom. In the figure before you is exhibited the whole history of the animal. Developing within itself certain rounded masses, these grow till they acquire a certain size, when the parent ruptures, and they are set free. The rounded masses thus set free, grow till they acquire their full size, when they, in turn, go through the same phases as the parent from which they were derived. Now, there is nothing like voluntary motion here—there is no evidence of sensation; and as for the vibrating cilia, they are no more than is met with in the spores of Conferva and Vaucheria.

PLATE V.



Volvox.

The spores of the Sponge, although freely locomotive, yet its motions are the result, as in the preceding instances, of vibrating cilia.

Another, though less exact distinction between the members of the Animal and Vegetable Kingdom, is the relation which they have to the atmosphere by which they are surrounded. The atmosphere is made up of oxygen and nitrogen. It also contains a certain quantity of water, either in the form of water, or of vapor of water.—There is still another element, carbon, which exists in the form of carbonic acid, but in a limited quantity.

Now Plants derive their nourishment directly from the atmosphere, receiving it in an elementary and an unorganized form, and subsequently convert it into the various tissues of which they are made up. These tissues, or analogies, give us the proximate elements—sugar, starch, gum—vegetable fibrine—vegetable albumen, &c.

Now turn to the Animal Kingdom. From what does it derive its nourishment? Almost entirely from the organized substances contained in Plants; drawing nothing from the atmosphere except oxygen, which is introduced in the process of respiration. The proximate elements, sugar, starch, gum, &c. are consumed by animals and appear in them, in the form of muscular fibre, nerve, bone and the various tissues of the body.

We have next to ask, what is the relation of the Animal Kingdom to the atmosphere? It gets nothing from it but the oxygen, for the purposes of respiration. Does it give anything back to it?

Before entering into the consideration of the classification of the various functions, I would call your attention to one more subject. We have the functions of animals to be described, and before we commence, it will be necessary to say a few words with regard to their principal subdivisions.

Animals are constantly giving back to the atmosphere carbon, in the form of carbonic acid; nitrogen and hydrogen, in the form of ammonia; oxygen and hydrogen in the form of water, or the vapor of water—precisely the ingredients which the plants have withdrawn from it. Thus the two kingdoms may be regarded as antagonising each other, when their relation to the atmosphere is taken into consideration. By arranging in a tabular form the characteristics of the two kingdoms we shall find each presenting the following properties:

Animals.	*Plants.*
Motions voluntary.	Motions involuntary.
Sensible.	Insensible.
Digestive cavity.	No digestive cavity.
Nourished by organic matter.	Nourished by inorganic matter.
Consume organic elements.	Produce organic elements.
Starch.	Starch.
Sugar.	Sugar.
Gum.	Gum.
Fibrine.	Fibrine.
Albumen.	Albumen.

Previous to the time of Cuvier, the Animal Kingdom was divided into many groups which were not natural. Cuvier undertook to arrange them all according to their organization—to arrange in one and the same great group, all those animals which seem to be constructed on one and the same general plan; and in passing them in review it was found that there existed four great plans of organization.

Of one of these we have already had an instance in the Hydra, (Plate III) a fresh water Polyp, consisting of arms, arranged around an axis, radiating from it, as from a centre. A similar arrangement exists in Star Fishes. The members of this series

and all the animals of this great group, Cuvier called Radiata.

On passing higher up in the scale, it was found that another group presented itself no longer radiated, but made up of a series of rings arranged one behind the other, as seen in the Earth Worm, where they are exceedingly simple, provided with legs for walking, as in the Centipede, or with the addition of wings for flying, as in Insects. These are called Articulated animals. The expression is perhaps not absolutely correct, because it supposes that joints do not exist in other animals. "Annulated," or Ringed animals, is a much more appropriate expression.

Passing further, we have another group of animals, but much more varied in their form, not presenting any external division into a series of rings, nor are they radiated as is the Polyp, as represented in Plate II. Although the arms may have a radiated form in some, as in the highest, the Nautilus, yet the integuments and nervous system do not. Their tissues are exceedingly soft and watery, and in consequence they are denominated Mollusca.

The highest group is characterized by the existence of a chain of bones, or Vertebræ, which not only serve to give points of resistance to the muscles, but form a canal for the protection of the nervous centres. To the Vertebral column are added appendages in the form of ribs, arms, legs, &c. But as the Vertebral column was the only part of the skeleton invariably present in this group of animals, they were denominated Vertebrata.

The nervous system presents a peculiar form for each one of these groups; and the appearances which the embryos of the members of this group present, are equally characteristic.

The following, then, are the primary subdivisions of the Animal Kingdom:

I. Radiata—including Polypi, Jelly-fishes, Star-fishes.

II. Articulata—including Worms, Insects, Crabs, Spiders.

III. Mollusca—including several principal forms, viz., animals like the Nautilus, Snail, Oyster.

IV. Vertebrata—Mammals, Birds, Reptiles, Fishes.

LECTURE II.

In the last lecture I attempted to draw a distinction between the members of the animal and the vegetable kingdoms. This distinction was drawn for the purpose of giving us a definition of an animal, and for establishing a point of departure in the consideration of the various processes of which animals are the seat. There was still another object in view; for by establishing this line of separation and getting the definition of an animal, we have also a means of forming a classification of the various functions of which animals are the seat.

It will be recollected that in considering the various functions of organized beings, some were found to be universal. Nutrition and reproduction exist not only in the animal, but in the vegetable series. Motion was found to exist in both series, but not universally in the vegetable. So that motion in itself could not be regarded as a distinctive character of animals. The next point was the kind of motion. Voluntary motion alone was found in animals, whereas all movements in plants were involuntary.

In classifying these various functions, they are arranged by Physiologists in two distinct groups. In one group are arranged all those functions which are found both in animals and vegetables—in all organized beings; in the other group are arranged all those which are met with only in animals. This classification may be thus represented:

Functions
- Organic
  - Nutrition,
  - Reproduction.
- Animal
  - Motion,
  - Sensation.

There is an objection to calling the first group *Vegetative* functions, a term used by Bichat and the French Physiologists, because this would seem to imply that these processes are met with only in the Vegetable Kingdom, whereas they are common to both—are universal among organized beings.

In studying the various phenomena, of which the lowest animal is the seat, we shall find many processes analogous to those which are met with in the higher races of animals, but reduced to their greatest simplicity.

Nutrition is *essentially* the same in the Polyp as in man, though the means by which it is effected in the two vary exceedingly in their complexity.—In the Polyp, (Plate II) the nutritive apparatus consists only of a stomach; but in the higher animals we have superadded parts for the mechanical separation of the food, others for its solution, and others for its introduction into the system. But in

and there dissolved, it is absorbed and appropriated without the aid of vessels or any complex apparatus.

As we ascend in the scale, we find, besides those processes which are subservient to the mere digestion—the solution of the food—others which are subservient to it, transferred to the different parts of the body. And this brings to our consideration another series of organs—the vascular system—the blood-vessels. These may be regarded as nutritive organs, because they are the carriers of nutritive fluid to different parts of the body.

There are still others—those subservient to the purification of the blood. The blood not only gives out that which is necessary for the nourishment of the body, but also receives the cast-off particles; and in order to separate these cast-off particles, which are injurious, we have organs for its purification, viz., respiratory organs and organs for secretion; or, as they are more generally called, for excretion. So that, under this head of nutrition we have arranged all those organs, whether more complex, as in the higher animals, or more simple, as in the Polypi—subservient to the renovation of the different tissues of the body.

With regard to the organs of motion, and those of sensation, those will all be arranged under another head, whether they be the simple surface of the body, as is the case in the Polyp, or the complex apparatus which exists in the higher forms, as the organs of sense, and the whole system of nerves and nervous centres.

We shall have arranged in another group all those functions which are concerned in moving the different parts on each other; and this may be contractile tissue, either associated with bones, as in the Vertebrates, or with an external skeleton, as in the Invertebrate Animals.

The order in which we treat of these functions is not very material. I propose to take up first, the function of motion, then that of nutrition, and afterwards the functions of the nervous system.

The functions of the nervous system will be more readily understood after we have considered some of the others.

It should be borne in mind that we must not infer that because an animal is low in the scale, that its motions are always inferior to those of an animal higher in the scale; for we find that there is a constant variation in this respect. When one animal is said to be lower than another, it is not because its motions, or any *one* of its functions, are lower, but because the totality of its functions are of an inferior grade; and this is the only rule for placing animals together in a series. Although a Mollusk is higher than a Radiate, yet in some instances the motions of the latter are far more complex than those of the former.

In looking to the lowest animal form for the motion of which it is the seat, the Hydra is found not only capable of moving about in space, but to have the power of moving different parts of the body upon each other. Every part is endowed with contractility; and although we cannot recognize a structure similar, precisely, to muscular fibre, yet in the organs themselves we have a contractile tissue. Among the Radiated animals which we have assumed as the lowest group, there is a great variety in their powers of locomotion, though in the main, the movements may be said to be quite slow, compared with those met with in the higher classes; while the Polyp in many instances remains stationary, as in the Coral animal, there are other members of this class which have the power of travelling about.

The apparatus of motion in the Star-Fishes is quite complex, while every part of the body in the Polyp is quite contractile. There are in the Star-Fishes and Echini certain organs set apart as moving organs. Suppose that to represent one ray of the Star-Fish; [the Professor here drew the figure on the black-board] on making a section through it you will find arranged along the inside of the ray, a series of vesicles, extending through its whole length, and connected with a contractile cylinder, projecting through the shell. The vesicle and cylinder are both filled with a fluid. These two little bodies are the two locomotive bodies of the Star-Fish. They may be moved about in various ways—may be projected backwards or forwards, and be applied to any body that may be near it. Suppose the Star-Fish wishes to move—the cylinder is projected, and the sucking disc with which it is provided at the free extremity, is attached to a neighboring body, and as it has the power of contracting, when it does contract, the animal is pulled along towards the point to which the cylindrical foot is attached, just as a vessel is pulled along through the water by the throwing out an anchor, and pulling the vessel towards it.—Then the cylinder is taken up and extended forwards again, and attached to another point, and by its contracting again, the animal is drawn further along.

There is still another form of motion, which, perhaps, might have been referred to, first of all, because it is, in some respects, a kind of motion effected by an inferior means, although it occurs in animals which are quite high up in the series. On this diagram are represented two figures of animals which are microscopic—which are invisible to the naked eye. One of them, the Vorticella, can be seen fixed to some substance in the water, being attached by a foot-stalk, which has the power of contracting. At the end of this, is situated the body of the animal itself, of a cupped shape; and upon the upper edge of this, bodies, which are similar to, if not identical with, vibrating cilia, such as have been shown to exist in plants. There is, however, this important difference, that while ciliary motions of plants are continual, the locomotive cilia of animals may be arrested or set in motion at the Polyp, being introduced into a simple cavity

tion again at pleasure; those of plants being incessant. The Vorticella being attached to some surrounding body, is incapable of moving in the water beyond the length of its foot-stalk.

PLATE VI.

Rotifer.

In the Rotifer, also, (Plate VI,) which is one of higher organization, you will find that there is arrayed around the upper part of one extremity, two crowns of vibrating organs, precisely similar to those in the Vorticella; and they are so arranged as to set in motion the water,—the current passing directly between them;—so that when the animals on which they prey are drawn in, they are readily secured by closing together the cups.

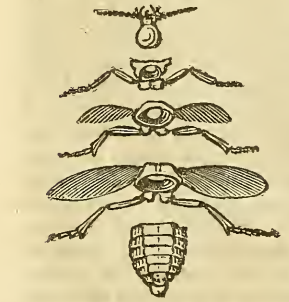
Of the Articulata, or animals made up of a series of rings, we have several representatives in these diagrams. First, a worm, in which the segments of the body are provided with appendages, in the form of hairs or bristles. Here is another—the Centipede, (Plate VII.) Here are insects and, here are Crustaceans. In examining the simplest of these, the worms, we find that the whole body is made up of rings, without legs, unless they be represented by hairs. Here motion is effected by the successive changes of position of the rings. There is nothing analogous to that of walking.—But in the Centipede (Plate VII.) we find that each one of these is provided with a jointed appendage, which forms a leg, and each segment of the body has its own leg, just as each segment of the body, (as we shall see hereafter) has its own brain or ganglion.

PLATE VII.

Centipede.

Among insects, the number of rings provided with appendages is only three, viz: the three rings following the head; but they are modified in form, to give attachment to muscles moving the legs, where they alone exist, as in the Spectum; or in addition to these the wings, as is the case in nearly all the members of this class, (Plate VIII). In Crustaceans, the same general structure prevails; in some instances, all the rings are provided with legs; in others only a limited number—as is seen in these diagrams, representing Branchipus and Lucifer.

PLATE VIII.



Highest form of Insect.

The motions of Mollusks are, in the main, exceedingly simple.

In many Mollusca which are fixed to some substance in the water, motion is effected only in the way that it is by the Infusorial Animalcule, and that is by vibrating Cilia. An Oyster which is attached to a rock, or to any other firm substance, does not move itself, but has the power of making the water to move around it, which it does by means of vibrating Cilia.

These different forms which I have referred to will give you some idea of the structure and of the different kinds of functions of motion in the Invertebrated animals. Still the description is very imperfect, because the variety in this class of animals is immense.

Leaving the Invertebrate animals, we now call your attention more particularly to the organs of motion as they exist in the Vertebrata. The parts which are represented on the various diagrams [which the Professor exhibited,] constitute the mechanical apparatus by which the moving power acts on different parts of the body. The bones of which the skeletons of Vertebrata are composed, are parts of the living organism, and are themselves alive—and in this respect differ from the corresponding parts of the invertebrate animals, which, once formed, completely lose their vitality, as is the case with the shells of Mollusks and the crust of insects and lobsters. The skeleton of the Vertebrates is the seat of changes which are continually going on. The bones are provided with blood vessels, by which they are nourished; for they are continually undergoing changes, although very slowly.

In order to form an idea of the skeleton, it will be perhaps desirable first of all, to call your attention to the material out of which it is made—to the composition of bone. In order to give the skeleton its necessary firmness and strength, bone is made up of a mixture of organic and inorganic matter—the proportion of these ingredients varying extremely in different animals and in different periods of the life of the same animal. The principal organic ingredient is Cartilage, or at least a substance very nearly resembling it. The inorganic portion is principally composed of Lime, chiefly in the form of phosphate and carbonate.

Here are three similar bones from the arm.—[The Prof. exhibited the bones to the audience.] One of them is in its perfect state, having all the power of resistance which it ever has. A second of precisely the same form, but which consists entirely of calcareous matter which enters into the formation of the bone, the animal substance having been entirely removed; it will be seen that the bone has completely lost its power of resistance, so that, with the slightest force, it breaks up into fragments, and has no flexibility. [The Prof. here broke the bone several times apparently with great

case.] Here is another bone which has been treated by acid. The form of the bone is still perfectly preserved, though all the lime has been removed, and now the bone bends in every direction, but does not break. Here is another, treated in the same way, which has become perfectly flexible.

Now the solidity, or firmness of the bones results from their containing a certain portion of the organic and inorganic elements. That proportion varies during life. In the earliest condition the bone is simply Cartilage. Afterwards the lime begins to be deposited. And in the human body, up to extreme old age, the inorganic portion is constantly on the increase.

In studying the skeleton to determine its structure in this class, if you refer to the diagrams, you will find that there is one portion which is always present in the Vertebrata, and that is the vertebral column, and to which the other parts are merely appendages. But before entering upon the consideration of the skeleton as a whole, it will be worth while to call your attention to the structure of a Vertebra—to ascertain what that is, and then we shall have a knowledge of its fundamental portion.

Every vertebral element of the skeleton may be said to be made up of the following parts. First, there is a central part or *body*, which gives it the power of supporting weight, or makes it a resisting centre for attaching the muscles. Next above the body of the Vertebra is a canal. This serves for the lodgement of the spinal marrow; and above this is a process which is almost invariably present; and on the sides here are other processes.—[The Prof. exhibited the enormous Vertebra of a Whale while making his descriptions.] But as this Vertebra comes from the portion of the skeleton which is situated near the tail, it does not contain all the elements which are found further forward. A complete Vertebra consists, in addition to the parts above mentioned, of an inferior arch, formed by the ribs, with their appended cartilages, and between which is interposed the breast bone, as is represented in this diagram, where all the parts are seen.

[Here the Professor exhibited a transverse section of the solid parts of the body, being the Vertebræ connected with the ribs and sternum]. The inferior arch thus formed serving to lodge the blood-vessels, as in the tails of fishes—the digestive organs, as in the central part of the body, or the heart and respiratory organs, as in man. The whole skeleton may be regarded, setting aside the head, of which we shall speak hereafter, as a series of Vertebræ with an arch above and below.

To analyze the skeleton a little further, there exist, besides these ribs, other appendages which, in fishes, are the rudiments of the legs in the higher animals, as is shown in the skeleton of the Gar, or as in another specimen. The vertebral column is in the middle; then the arch formed by the ribs; then as appendages to one of these arches, are the

PLATE IX.

Skeleton of Gar Fish.

representatives of the legs, and to another, a pair of fins, which are the representatives of the arms.

Here is represented the pectoral fin of a Fish, where we have an approach in the structure of the part to that which exists in the arms or legs of the higher animals.

We have next to look at the skeleton and see how it is constituted, in order to make a locomotive apparatus. Among fishes the locomotion is effected almost entirely by swimming, as they live in the water. And the organs corresponding to the extremities of other animals are reduced to the lowest degree of simplicity. The locomotive organ, consists, in the fish, of a tail.

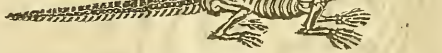
The fins on the lower side, occupying the position of the legs and arms, are not true locomotive organs. They serve only to modify the direction as the animal passes through the water, or may answer, as is more common, only for the purpose of balancing the body. The fins above and below serve only as keels, and will prevent the Fish from sliding through the water, and going to lee-way when he changes his direction.

We find some organs in some Fishes arranged for crawling, as in the Cheironectes, a Fish which crawls on the shore like a reptile. Then you have, in the Flying Fishes, fins acting as wings, capable of sustaining them for a short time, at least, above the water. So you see that swimming, crawling and flying are met with in Fishes.

In passing to the next highest group of vertebrated animals, we come to the Reptiles.

The lowest of reptiles, as the Siren, are swimmers, living in the water entirely, and swimming by the tail alone. But as we ascend higher we find the skeleton is provided with the means for walking on the land, as in the Crocodile (Plate X), and in the reptiles resembling the

PLATE X.



Crocodile.

Lizard. It is in reptiles we for the first time find the anterior fin assuming the form of a hand, so as to be able to grasp the surface over which they are moving. But still the body is only slightly raised above the ground—they simply crawl.

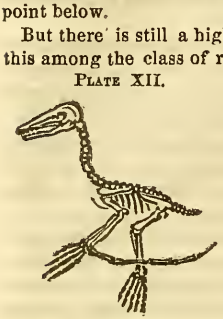
PLATE XI.

Skeleton of Rattle Snake.

Among reptiles, we find in addition to those that crawl upon the surface, that there are others which climb, as the Chameleon; and to go still higher, there are those which approach to the flying of birds. There is one, a little Lizard, a few inches in length, which is called the Flying Dragon, where the ribs are elongated and covered with a thin membrane, so as to form a parachute like that of the flying squirrel; and this enables them to fly with ease from an elevated position to a distant point below.

But there is still a higher kind of motion than this among the class of reptiles. We have represented here (Plate XII) the restored skeleton of an animal which does not exist in the present condition of the globe. It is only known in a fossil condition. Cuvier, on examining the bones as they were presented to him, made an effort to determine their true value. Looking at the head to determine whether it were a bird, a reptile, or a quadruped, it was obvious that it was not a quadruped, from the fact that a bone which he discovered at the base of the skull, where the lower jaw joins with the head, was a bone which exists only in the race of birds or reptiles. That it was not a bird, was shown from the fact that it had teeth. Cuvier found that the parts corresponding to the arms and legs were similar to the Lizard's, except one portion. There was found to be a series of bones connected with the hand, extending for a long distance beyond the other fingers. The question naturally arose with regard to the use of this part; and in attempting to find a use for it, he found something analogous to it in one of the higher animals, viz., the Bat (Plate XIII). All the other parts are constructed on the same plan as Lizards in general, with the exception of this finger, which extended far beyond the others; to serve according to Cuvier, for stretching a membrane extending from the fore arm to the side of the body—thus forming an expanded surface for striking the air.

Plate XII.



Pterodactyle.

Plate XIII.

Skeleton of Bat.

In reviewing the class of Reptiles, we have the kinds of motion by which they are characterized: first swimming, then crawling on the ground, then climbing, then flying in the air. There is a modification of the skeleton yet to be noticed, which is very peculiar. On looking at the skeleton of a Tortoise, the question very naturally arises, what part of the skeleton enters into the formation of the shell? On looking within, we find the vertebral column extending along the whole length; and attached to it are the ribs, but so expanded that their edges meet and form a continuous shell.

In passing from the class of Reptiles to that of Birds, we have the vertebral type still prominent. The typical motion of the Bird is that of flight.—The parts corresponding to those of the arm, and the whole skeleton even, are modified. In the first place, we have to look at the vertebral column itself. Usually the vertebral column is very flexible; but here, as there is great resistance to be maintained in consequence of the great muscular power required for flight, the vertebræ of the trunk are so united together as to be but very slightly moveable, and the ribs which sustain the breast bone, and to which the wings are attached, are stronger than in any of the other races, either above or below in rank.

With regard to the parts corresponding to the arm, those are likewise modified to a very considerable extent. Thus in the Eagle, (Plate XIV.) which is the bird ranking the highest, we have the wing divided into three parts; we have first the arm, then the fore-arm, and finally the hand. We have others supporting the hand without having a great surface exposed. In looking through the skeletons of Birds with reference to motion, we have the same kinds repeated, as existed in Reptiles—beginning with the Swimming Birds, with this difference, that Birds swim by their legs, and not by their tails. The arms are so modified as to form paddles, as in the Penguin, and not wings for flying in the air.—But there are others in which the power of walking alone exists, as in the Apteryx, which resembles very much an Ostrich, the wings being represented only by the simplest rudiments. We have, then, Birds which are simply swimmers, others walkers, and others flyers.

Plate XIV.

Eagle.

Plate XV.

Mammal—Bear.

Among Mammalia you have the same kind of motions presented as exists in Birds. There exists a series of animals whose motions are similar

to those of Fishes, as in the Whales; another to those of Reptiles, as in the Otter, which swims in the water, but on land, in consequence of its short legs, draws its body along as the Crocodile does. Then we have animals walking on all fours, as the Bear. And finally, animals in which the skeleton is adapted to flying. But in Man we have the skeleton adapted for a peculiar kind of locomotion, that of walking erect on two points of support, which exists in no other member of the animal series. Of the motions of Mammals, it is impossible to give a thorough account, in consequence of their infinite variety of form. But I will ask your attention to these various figures. [Here the Prof. exhibited a large number of diagrams, intended to represent modifications of corresponding parts in different animals, which at first sight seem entirely dissimilar].

[He also exhibited a series of diagrams, showing the transition forms from the single finger of a horse, intended merely for locomotion and support, to the five fingers of the lion, intended for support, motion and seizing; and from this to the hands of man intended for prehension and touch].

LECTURE III.

In the last lecture, it was stated that the substance, of which the skeleton of the Vertebrata was made differs entirely from that of the invertebrate animals, in being a part of the living body—the bones being supplied with blood-vessels, the particles of which they are composed changing from time to time, though slowly. In reviewing the skeleton it was shown that the vertebral column formed a central axis, either for the support of the weight of the body, or forming a point of resistance for the muscles; and above, there exists a canal lodging a spinal cord, and below, a series of arches formed by the ribs and the pelvis, for the lodgment of the blood-vessels and organs of respiration, circulation, and digestion. To these arches formed on the under side of the vertebræ, you have appendages which in fishes foreshadow arms and legs, and on the higher animals, these same parts are modified with reference to the uses which they have in the economy of the animal to which they belong. We have animals whose motions are effected by the vertebral column alone, which is the case with fishes; but in the class above these, as in reptiles, the arms and legs are capable of sustaining the weight of the body so as to enable them to crawl.

In birds, the skeleton is modified with reference to flight, though some members of this class are purely swimmers, as the Penguin. Among Mammals in the Vertebrated animals, all the kinds of motion met with in the lower classes are repeated. Here we have a Dugong, an animal allied to the Whales, locomotion being effected by the tail alone, the legs not being developed. Next, you have the Walrus, an aquatic animal; the vertebral column not being subservient to the purpose of motion, but the arms and legs forming paddles. After that, you have the skeleton of a Polar Bear, (Plate XV); the body sustained at a distance above the ground, and the hands capable of a much greater variety of motion than exists in any of the inferior forms. Here you have another modification which exists in the Bat, (Plate XIII), where the skeleton remains the same as it is in the lower animals, except the hand is so modified as to form a wing. You have bones of the shoulder, of the arm, the fore arm, the wrist; but instead of the fingers, as they exist in other Mammals, they are elongated so as to form stretchers to the membrane by which they act upon the air.

In passing from the Cetacean to the Bear, and still further, to the Orangs, you pass towards the conformation seen in the human body; but still there is a marked difference between all the inferior animals and man, and it is to these differences that I wish to call your attention at the present time.

I will commence with this proposition, that there is no animal, Man excepted, capable of standing erect on two feet. Birds are no exception to this, for although they stand on two feet, yet the position of the vertebræ is such as always to form an angle with a horizontal line; and at the same time, the legs are bent in a series of angles, and thus, though resting on two points of support, they do not yet stand erect. Before contrasting the skeleton of Man with that of the lower animals, I will say a few words with regard to those races which more nearly approach Man; viz. the Orangs. There are five species of Orangs known at present, two of which are met with in Africa and three in Asia, or the islands in the immediate vicinity—Borneo, Sumatra, Java.

Of the African races there are two, but the one most commonly known is this (the Chimpanzee

Plate XVI.) It differs from the Asiatic species in the color of the skin; the hair is nearly black, while that of the East India Orang is of a brown color. You will see the difference in the size of the ear of the two; in the last, it is quite small, while in the African it is excessively developed, enlarged. The African Orang has prominent ridges over the eyes, which are almost deficient in the Asiatic species; while the latter has arms reaching to the feet, (Plate XVII), those of the African reach only to the knees, (Plate XVI.)

In contrasting the skeletons of these animals with that of the human body, Linnæus, considering only their anatomical character, confesses his inability to see any difference whatever. In his work entitled Fauna Suecica, he says: "hitherto, I have been unable to detect any character by which a Man can be distinguished from an Orang."

Before instituting comparisons of Man and the Orang with each other, I will call your attention to the different parts which exist in the human skeleton. They are, however, a repetition only of those parts which have been seen before. We have here, as in the whole Vertebrated series, a vertebral column, terminating above in the skull for the lodgement of the brain and the organs of sense, and giving attachments to the jaws.

In studying the human skeleton with reference to its adaptation to the erect attitude, we have to enquire what is necessary in order that it may be balanced on the two feet. The centre of gravity of the whole body must fall either between the two surfaces of support or upon one of them; and in order to obtain this end, the followlng conditions are necessary: first, that the head should be very nearly balanced on the vertebral column; second, the curves of the vertebral column should be such, that the trunk shall be balanced on the heads of the thigh bones. The thigh bone and the two bones of the leg should be in one and the same vertical plane; and lastly, it is necessary that the foot should be so arranged as to form a right angle, or nearly so, with the leg.

Let us examine the skeleton of the Orang, and see how far these characteristics exist. And first, with regard to the head. If you look at the under side of the skull you will see an opening, through which the spinal marrow passes out, and on each side of this there are two articulating surfaces for uniting the head with the upper part of the vetebral column.

Now, if you look at the human skull, for the position of that opening, at the base of the skull, you will see that the anterior edge is very nearly in the centre of the base, but that the articulating processes are a little behind this point; so that there is a tendency for it to tilt forward. But this tendency is counteracted partly by the situation of the larger portion of the brain behind this centre, the parts about the face being almost hollow, forming the organ of smell and the cavity of the mouth. Thus the head is very nearly balanced, but not quite. For if left to itself, even in the living body, it has a tendency to fall a little forward. In the Orang we find a little deviation. Here is the skull of a Chimpanzee (or African Orang), and on looking for the position of this opening and for the articulating surfaces, we find that instead of being in the centre they are much further back; that is, if you divide the base of the skull into three equal parts, you will find the hole to be in the last third. So that not only the face but a large portion of the skull is in advance of the centre. Thus you see it has a tendency, when left to itself, to bend still more strongly forward than in man. In the other African species (the Engeena), which we have here, on comparing the relative position of this opening, it is also found to exist in the posterior third; and in this species also the head cannot be balanced.

On looking at the skull of an animal still lower (a Bear), this opening is found quite at the back part of the head. Thus the Orang, in regard to these points, is found to occupy a position intermediate between man and the lower brutes.

Here then, is one deviation, an important one, from the condition which exists in the human body.

In comparing the varieties of the human race with each other, to ascertain if any approach to the condition referred to exists in them, it may be said that the deviations which take place in human cranla, are insignificant when compared with those existing between man and the Orangs.

The next portion of the skeleton to be considered is the vertebral column, its form and curves. If you examine the general direction of the vertebral column in the human body, you find that, although it presents a series of curves, yet, at the lowest part, it is so far curved forward as to bring a'l the parts above over the point on which it rests. If you view the vertebral column sideways you find that the lower part is curved inwards, so that all the weight of the body above is brought to bear very nearly on the base. This is a condition of things which does not exist in the Orang. For if you compare the

[Plate XVI.] [Plate XVII.]

Chimpanzee. *Asiatic Orang.*

skeletons of either of these, the African or the Asiatic Orang, you find that in the natural attitude of the Orang, when climbing, the whole body is bent forward, the spine forming a large curve, the concavity directed forward, towards the anterior part of the body. Now the inferior part of the human vertebral column is convex forward, which causes the base on which it rests to be advanced, and the cause of these differences exists in the form of the bones themselves. For if we examine the vertebræ of the loins from the human body, looking at them on one side, it will be seen that they have this form—they are the broadest on the anterior face, so that a series of them piled one above the other would give a convex surface forward.

Now, if you examine the corresponding vertebræ in the Orang, you will find this difference. Instead of having the broadest part in front, they are there the narrowest, so that the series of bones will have a concave surface. The effect of this arrangement is in man to throw the centre of gravity forward. over the centre of support, and in the Orang, behind it.

There is another subject which I ought to refer to, and that is the general form of the vertebral column. If it is examined in the human body it will be found from the upper part, downwards, to grow gradually larger and larger, and as the weight becomes greater and greater, the size of the vertebræ becomes enlarged in a corresponding degree. But in the Orang there exists only a very slight increase in size, in the corresponding parts, indicating that the weight of the body must receive some other support, than from its base.

In examining the pelvis, you see a remarkable difference between the pelvis of the Orang and that of the human body. It hardly requires any thing more than to put the two side by side, (this the Professor did) to see how they differ. Comparing it with that of the Bear you see it resembles that much more closely than it does the pelvis of the human body. Here is the same in the African Orang, which in the main, approaches nearer to that of the human skeleton, taking all the bones into consideration, than the Asiatic Orang does.

The bones of the legs in Man and the Orangs are strongly contrasted, as regards the transmission of their weight through their bases. If you place the thigh bone of Man so that the lower extremity rests upon a table, you will find that any weight resting upon the head of the bone, is transmitted vertically towards the centre of its lower extremity. In placing the whole leg in its natural position, the bones of the leg are perpendicular, but the axis of the thigh bone is not perpendicular,and yet the head of the thigh bone is so far thrown inwards at the neck, that any weight resting upon it is transmitted vertically upon the bones of the leg below. Thus all tendency to deviate from one side to the other is counteracted. This is not the case in any of the Orangs. The lower surfaces of the thigh bone are so formed, that the weight of the body falls inside, and, in fact, the leg and thigh form an angle with each other projecting outwards.

In following the skeleton still further down, we find another point of difference in the position of the foot with reference to the leg. Man, alone, has power of placing the foot at right angles with the leg, and, at the same time, the sole of the foot resting on the ground. This exists in the human skeleton, and in that alone. For, if you contrast the foot of Orangs with that of Man, there is this important difference. In the Orangs, instead of the sole being in a horizontal plane, it is turned inwards, so as to adapt it to the trees on which it climbs. In walking on the ground, the Orang always stands on the outer edge of the foot, which always renders its motions exceedingly awkward.

But there is another peculiarity, and that is in the size and position of the great toe, which is a characteristic of the human race. If you look at the skeletons of the lower animals, this part is much smaller instead of being much larger, than the other toes. Here is the foot of the bear, and the part corresponding to the the great toe in man, is the smallest of the whole series. This development of the great toe in the human body has especial reference to the increased weight transmitted to it, and to counteract the tendency of the foot to turn inwards. But to counteract that, the great toe is enlarged to a corresponding degree. In Orangs, and the same is true of the Monkeys generally, there is this important difference, the first toe, instead of being on a line with the others, always forms an angle with them. It has precisely the structure of a thumb. Look at the foot of the East India Orang. You have the great toe capable of being opposed to the other toes—as the thumb is in the hand of man. The same is the case in the African Orang, the great toe being detached from the rest, in order that it may be brought in opposition to them, and enable it to seize the limbs of trees on which it climbs.

PLATE XVIII.

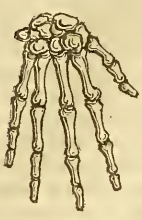
Foot of Cebus.

In carrying the comparison of skeletons still further, we find remaining the arms. These, in the Orangs, are but very little different, with regard to the number of parts of which they are made up, though there exists a striking contrast in their proportions.

You have in this animal (the Chimpanzee or African species, Plate XVI,) the shortest arm which exists in any species of Orang; and on placing it at the side of the body it comes down to the knee. In the East Indian Orang when the skeleton is hung up erect, the tips of the fingers come down to the ankles. (Plate XVII.) The fingers also are more largely developed, but the thumb very imperfectly so. Here is the cast (which the Professor exhiblt-

ed) of the hand of the African Orang. In its general formation it resembles that of the human hand, excepting only the thumb. If you look at that you will see that instead of extending to the middle of the index finger as is the case in the human hand, it is so short that it does not reach to its base and cannot be brought in opposition with the tips of the other fingers. The same is true of all the Monkeys. You have in this diagram (Plate XX) a Cebus, or South American Monkey, where the thumb is merely a rudiment, consisting of a single bone. The fingers are long and curved, and the only use to which they are subservient, is that of forming a sort of hook for grasping the branches of the trees upon which they live, and by means of their long arms, for swinging from one branch to another.

(Plate XIX.) (Plate XX.)



Human Hand.

Hand of Cebus.

In consequence of this conformation of the hand, the Orang is obliged to hold a body with two hands. Man alone can hold bodies by placing them with the fingers opposed to the thumb.—Sometimes, however, the Monkey does hold a body with one hand; but it is by pressing the body between their fingers and the palm. But sometimes, as when Monkies are taught to thread a needle, the thumb is placed against the *side* of the finger, never against the *tip* of the finger.

These points of distinction are sufficient to show that the human skeleton, as regards its attitude, is constructed in an entirely different manner from that of any of the lower animals. And, indeed, the Orang can be said to approach but very little nearer to it, as regards its adaptation to the erect position, than animals still lower in the scale. For while on the ground, its natural attitude is to stand on all fours, instead of standing erect on two feet; in spite of what has been asserted by travellers, and even by naturalists, who have described them as walking erect on two legs. On examining the knuckles of the African Orang, a hard callus is found, which is produced by their walking with these on the ground. But the East India Monkey walks in a different way, placing the palm upon the ground.

In reviewing the conditions necessary for an erect attitude, they may be said to co-exist in man, and in man alone; they are not found in any of the Anthropoid animals hitherto described, nor is there any nearer approximation to them in the species now under consideration, unless it be the existence of a pelvis a little more perfect in its conformation than in its congeners. The natural attitude of the Orangs on the ground is *semi-erect*, aided and supported by one or both of their long arms; the Chimpanzees and Orangs resting on their callous knuckles, and the Engeenas on the palms of their hands. If they at any time support themselves on their legs alone, their heads droop, the trunk is bent forwards, the thighs are flexed, and their feet inflexed, all which necessarily results from the mechanical arrangements of their skeleton. The *foramen magnum* and (consequently the occipital condyles), instead of being situated in the middle of the base of the skull, as in Man, is situated in the middle of the posterior third, from which results the greater preponderance of the head forwards.*

The vertebral column is concave throughout nearly the whole of its anterior face, and in the lumbar region especially, deviates from the form of that of the human body, in which it is strongly convex. This results from the anterior portions of the bodies of the lumbar vertebræ in the Orangs having the vertical diameter of the anterior face shorter than that of the posterior, so that when they are piled one above another, the superior ones incline forwards, and will necessarily cause the whole superimposed trunk to preponderate in that direction, consequently throwing the centre of gravity forward in a proportional degree.

The bent position of the body necessarily involves a greater or less flexion of the legs, in order that a portion of its lower part should be thrown behind the centre of gravity, to compensate in a measure for the upper portion including the head, which is thrown in front of it.

Lastly, the feet are always inflexed, in consequence of the mode of their articulation with the leg. Living habitually in trees, and the natural locomotion being that of climbing or swinging from limb to limb by the aid of long and powerful arms, their feet are so constructed as to enable them to apply the soles against the sides of the trunks and branches, consequently requiring them to be in planes, either really in, or approximating to a vertical direction. When on the ground, therefore, they are from necessity obliged to walk on the outer edge of the foot, and this with the

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*The position of this foramen in the Orangs is correctly regarded as an evidence of degradation. Soemmering has imagined that an approach to it existed in the crania of Negroes, and his statement has been frequently repeated by subsequent anatomists. The more recent observations of Owen and Pritchard however, have a tendency to show that this foramen does not occupy a place in the Negroes materially different from that of the Caucasians: so that the difference between the Negroes and Orangs with regard to this peculiarity is vastly greater than between any two of the human races. See Pritchard, Res. Phys. Hist. Man. 4th ed. vol. i. p. 290.

other peculiarities of their organization, gives them an unstable gait, contrasting with that of man, who, habitually walking erect on a horizontal surface, has the soles of the feet necessarily in a horizontal plane.

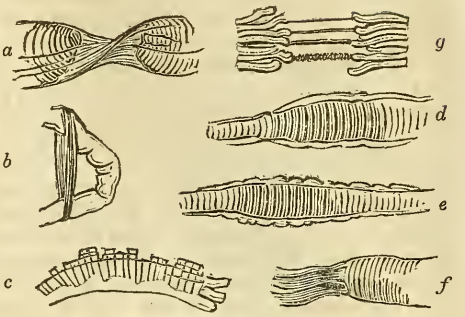
Having spoken of the skeleton, I have next to call your attention to the force or moving power, by which the parts of the skeleton are set in motion. The movements of animals, as has been already stated, are effected in two ways; first, by the vibration of organs similar to those met in the spores of some plants. Whether they be perfectly identical, remains yet to be shown; at all events, thus far no perceptible difference has been shown as regards the cause of their motion. The only difference between these, in the animal and vegetable kingdoms, being the voluntary nature of the former and the involuntary nature of the latter.—The spores are in incessant motion throughout the whole existence of the plant, or, at least, throughout its locomotive existence.

In the animal bodies, in addition to the movements effected by cilia, there are others produced by a tissue of contractility; contractility being nothing more than a tendency to change form under a stimulus, whether that stimulus be natural or artificial. In the Hydra no distinct tissue has been discovered which is the seat of this contraction. The whole body changes its form. The property of contracting does not seem to be delegated to any special part. But in examining the higher Polyps you will find that there is a tissue whose duty it is to contract and produce all the motions of the body. Now, that contractile tissue is known under the name of muscular fibre. Muscular fibre, as it is presented in the animal series, exists in two forms; one which is wholly under the control of the will, and the other which is entirely beyond its reach. All the movements which are effected by the will—of course, locomotion among the rest—are voluntary movements. But there are other movements of vegetative or organic life, which are effected by a series of fibres not under the control of the will.

In studying these it will be necessary, first of all, to analyze, as far as possible, the elements of which the muscle is composed. If you examine the muscle as a whole, either of the human body or of animals, you will find that it has the appearance, on the surface, of being made up of fibres, or of bundles of fibres. If you examine them carefully, you will find that they are made up of bundles of fibres, smaller and smaller, until you can carry them no further with the naked eye. On placing a bundle of fibres of a voluntary muscle under the microscope, you will find that they have a series of transverse lines or striæ.

And on examining it still more carefully, it will be found that an ultimate muscular fibre is tubular, as shown in these figures. In this (Plate XXI, fig. *b*) the sheath is torn, and the contents protrude. Here the contents are broken, but the

[Plate XXI.]



Muscular Fibre.

sheath remains entire. (Plate XXI, fig. *a*). With regard to the cause of this peculiar appearance of the transverse striæ, anatomists are somewhat at variance; but it is supposed to be in consequence of the mode in which the muscular fibre is made up. The contents of the sheath are composed of a series of globules, arranged very regularly, their convexities causing the sheath to project in definite lines. These globules are shown in Plate XXI, fig. *c*.

Thus we have muscular fibre. On examining the fibres, as they exist in themselves, they are found to extend from one of its extremities to the other. This is not the case in those muscles not under the control of the will. They vary exceedingly in the various animals, and in different parts of the same animal.

No relation has been found to exist between the size of the various animals and the size of the muscular fibre. Many very small animals have large muscular fibres. For instance, in the Fly you have the muscular fibres the four-hundredth part of an inch in diameter, which is about the same as it is in the human body. In some fishes you have fibres as large as the sixtieth of an inch in diameter. The only relation which may be said to exist between the size of the fibre and any other character is its irritability. Where the fibres are of the largest size there the irritability is found to be the greatest.

The fibres of muscles are combined in different ways according to their position and their use.

But to enter into a description of the details as seen in the animal series, would be entirely inconsistent with the time I have at my disposal.

In the application of muscular force, force has to be used as in a machine. There must be a point of resistance—the moving power and the part to be moved. The bones offer the fixed points, or points of resistance; the muscles, in virtue of their contractility on the moving powers, and the bones, the skin, and various other organs, are the parts to be moved.

There is one other element in the muscular system, and that relates to the movement of parts at a

distance from the muscle. In some instances muscles are attached directly to the parts which are to be moved. But occasionally it happens, especially in the human body, that the moving power is situated at a distance from the part which it moves. In that case you have situated between the two a part called tendon; an unelastic and insensible tissue, endowed with a great degree of strength and occupying a comparatively small space. An illustration exists in the muscular apparatus of the hand. The muscles by which the different fingers are moved do not surround the fingers themselves, but are situated high up on the fore arm, and the power generated by them transmitted to the fingers through the tendons. If they were situated on the fingers they would render them so clumsy as to destroy their adaptation to the nicely adjusted motions.

The next point for consideration is the condition of the muscle in a state of activity—during its contraction. This has always been an object of interest among Physiologists. We have at the outset to ask what are the most obvious appearances of muscles while contracting? First, there is a change of form, and it would seem to be indicated by appearances, that there is a change of size. But this is not the case; for there is no proof that it actually contracts, or that any thing but changed form exists. If a muscle be made to contract in a vessel of water, no change of level takes place, which would be the case if the bulk were in any way altered.

When we examine muscular fibre under the microscope, we find that the principal changes during contraction are the following: the fibres, at the same time that they shorten, become broader—and the transverse lines are approximated, as in Plate XXI, figs. *e* and *d*.

It has been proved beyond a doubt, that a fibre very seldom contracts throughout its whole length at one and the same time. One portion commences contraction, remains contracted for a short time, then another contracts, and the former becomes relaxed; so that there is constant change in this respect, no one part continuing in activity for any great length of time.

There are various stimuli which will produce these contractions; among them mechanical irritation or galvanism, and the influence derived from the nervous system.

The muscle of an animal recently killed, if irritated with the point of a pin, or if you pour upon it some irritating acid, or if you strike it, contracts, and if you apply galvanism to it, it will contract more powerfully than under the influence of any other physical means. In consequence of its being stimulated so readily by galvanism, it has been a favorite theory among Physiologists, that galvanism is the influence of the nervous system—is "nervous force." I will not anticipate my remarks upon this subject, but will only say that there has not yet been found any identity between the "nervous influence" and galvanism.

In order to produce muscular contractions, three things are necessary; first, the nervous agency; secondly, the conductor to carry that influence to the part to be contracted; and lastly, the contracting fibre. Suppose you have a single fibre to be acted upon. On tracing the nerves to the muscles, they are found, in all cases, at one end to be connected with the nervous centres, and at the other to form a series of loops around the muscular fibre. You can prove this by the aid of the microscope, and can trace the nerves through all their passages among the muscular fibres, but in no instance do they pass *into* the fibre itself.

Now, the nerve itself comes from the spinal marrow, or from the brain—suppose from the spinal marrow. The influence is transferred along the nerve and around the fibre, but not *into* it.

LECTURE IV.

It was my intention in the last lecture, before concluding the subject of Muscular Action, to have said a few words with regard to the manner in which muscular force is applied in the animal economy.

In studying the skeleton with reference to its uses, we have it subservient to two important ends: first, affording points of resistance to the muscles; secondly, constituting a series of levers for the application of muscular force, either for the purpose of increasing power or of multiplying the speed with which the different parts are moved.

In looking through the skeleton, we find examples of the three kinds of levers which are recognized in mechanics; one of these, called the "lever of the first kind," having the following form, (which the Professor showed on the board,) the points on which it turns, or the fulcrum, existing at some point intermediate between that to which the muscle is attached, and that on which the resist-

ance rests, the force being applied at one extremity and the resistance at the other. On looking through the skeleton for instances of this form of the lever, they are found to be very few. The bones of the vertebral column are levers of this sort. The articulating processes are the fulcra on which they turn,and the spinous processes form the arm of the power, and at the other end of the body of the vertebra and the weight it supports, the resistance. If the body be bent forward, the muscles of the back are enabled to raise it, acting on the processes of the vertebral as so many arms of a lever. The head itself may be regarded as a lever of this sort. The head turns on the vertebræ just as a lever turns on its fulcrum. There is still another form which is somewhat different from this, denominated in mechanics, "a lever of the second kind," where the point on which it turns is at one extremity, and the force at the other, and the weight to be overcome at some point between the two. This is considered the most powerful, because the arm of the force equals the whole length of the lever. Instances of this kind are not numerous. You have one in the foot. The "ball of the foot," where the toes are articulated with the bones which form the instep, constitutes the fulcrum; the length of the lever will be the distance between this and the heel to which the force is applied, and the resistance the weight of the body resting on the small bones of the foot.

The efficacy of this form of the lever will be all the greater in proportion as the resistance is nearer to the point on which it turns. But if you look at the foot, it will be found that the resistance is nearer to the point to which the force is applied than it is to the fulcrum; consequently the power is not applied at the greatest mechanical advantage.

There is still a third form, where the resistance is at one extremity, the point on which it turns is at the opposite one, and the force is applied at some point between the two. It may be either near the resistance which is to be overcome, or near to the fulcrum. The nearer it comes to the point on which the lever turns, the greater will be the disadvantage in the application of force; and if we look through the animal kingdom we shall see that this kind of lever is the one which most generally prevails. It is the lever formed by all the bones which assist in locomotion, especially in the movements of the arm and leg.

This preparation,(which the Professor exhibited,) is intended to illustrate the manner in which muscular force is applied in the movements of the fore-arm. You have the string which passes over the head of the bone of the arm, (the humerus,) representing the muscle by which the arm is to be moved; the fore-arm is the lever, and the resistance to be overcome is the hand, or any weight held in the hand. Now the muscle by which it is moved has its fixed point in the shoulder, and at the other end is attached, at a short distance from the fulcrum, on which the fore-arm turns, the elbow joint. That such an application of power involves a disadvantageous expenditure of force, will be obvious from the following considerations: If the muscle acted directly upon the hand, the only force required would be one equal to overcoming the weight of the hand, or of whatever might be held in it; the arm of the power and the arm of resistance would be equal, as both are equally distant from the fulcrum. If the muscle were attached to a point midway in the fore-arm,then the amount of the resistance would be double that of the power, consequently the force required to set the arm in motion must be doubled.

I will place a single ounce in the palm of the hand of this preparation; three ounces are required to set it in motion. Theoretically there would be but two; the additional ounce is necessary to overcome the friction of the artificial joining. So that if you have a pound in your hand, it will require a muscular effort of two pounds to sustain it. Now we will attach the muscle still nearer to the fulcrum at the point where it is placed naturally, viz: at one-sixth of the distance of the palm of the hand from the elbow joint. Now place in the palm of the hand this same weight that we did before. In the former case, making allowance for the friction, it required two ounces to raise it. Now there is one, a second, a third, a fourth, a fifth, a sixth, which will start it, with a little assistance. Theoretically there should have been five ounces, which would have set it in motion; but as before, an additional ounce is required to overcome the friction. So that to support a single pound in the palm of the hand, the muscle must exercise a force of five pounds. We have then, in this case, force applied at a great disadvantage; and the question which next arises, is,whether there is any compensation for this apparent waste of power. Suppose the muscle, instead of being attached at this point, was attached directly to the hand; then you have, first an inconvenience arising from the direction of the muscle. If the muscle passed in a straight line from the shoulder to the hand, if the elbow be bent at a right angle, then the arm would lose all its compactness, in the general arrangement of the muscles. But, there is still another inconvenience, which is this: you will notice the distance through which the cord moves in order to raise the fore-arm to the shoulder, when it is attached to the hand at a distance of six or eight inches. But if you apply it in its natural position, near the elbow, then the muscle contracting an inch or an inch and a half, you have even a greater amount of motion of the fore-arm than before,when it contracted six or eight inches. Consequently, while the muscle contracts through the space of an inch and a half or two inches, the hand is moved through six or eight times that space, and in the same period of time.

In looking at the various segments of the limbs, you find that this principle pervades the whole; viz., power applied at a mechanical disadvantage; but in all cases, there exists a compensation in the increase of speed and distance, through which a part is moved.

The next class of functions to which I desire to call your attention, is that class of functions and of organs which are subservient to the process of nutrition. The necessity for the existence of this class grows out of a law which pervades all organized beings. It was stated in the introductory lecture, that one of the characters by which living beings are distinguished from those which do not live, was the fact that they were in a state of incessant change. One series of particles of which they are composed are constantly entering, and another as constantly disappearing; so that Cuvier regarded living beings as so many "vortices," or whirpools, with their entering and departing currents.

While this change of particles continues, while this goes on, a being lives; when this ceases, life is no longer present; it is dead; the activity of a given being will be represented by the rapidity with which these changes take place. Of this we have a positive evidence, in examining the various members of the animal series. If you will compare, for example, the amount of matter thrown off during respiration from a Reptile and a Bird, it will be found that there is a much larger amount from the latter than the former, the muscular energy of the Bird being greater than that of the Reptile. Lavoisier determined that a Bird separated more carbonic acid by respiration than a Guinea Pig of several times its size. The same body undergoes more rapid changes during a state of activity than during a period of rest.—A man who has been actively exercised, gives off more carbonic acid than the same person will do during the state of repose. But it is not necessary to compare the same individual with himself at different times, but different parts of the same body may be compared at one and the same time. Those portions which are the most active are the most constantly changed, as the brain and nervous system; while those which are merely passive are changed far more slowly. It may be asked, "how do we know that the parts of which the brain is made up change more rapidly than the bones?"—This may be shown by the degree of vascularity.—Where there is rapid circulation of blood, that is an indication that the parts require constant renewal. Thus functional activity is always accompanied with a corresponding rapidity of disintegration of the constituent elements of the body. If then, there exist this tendency to change, there must exist, too, means by which these changes are effected. In studying the different members of the organic world, with reference to this, we should expect to find a great variety in their complication; depending in some measure on the kind of food by which they are nourished. Plants deriving all their food from the atmosphere, can absorb it without the necessity of a complex apparatus.—Animals, however, living on organic matter, are obliged to change the condition of the food, and reduce it to a condition capable of being absorbed. The simplest animal which we have had for examination, the Hydra, living as it does upon organic matter, that matter not being in a state proper for absorption, but must be reduced first to a liquid condition.

The processes by which the cast off particles are separated, may also be more or less complicated.—In the Hydra, this takes place in the tissues, and it passes through the organs without any one part being adapted to this more than any other. But, as you ascend in the animal series, you find that a division of labor exists here—that one part of the effete matter is thrown off by the lungs, another by the skin, and another by the various secreting organs.

In looking through the animal series with reference to a classification of nutritive processes, we may arrange them all under one of two heads,—First, those which are subservient to the introduction of nutritive matter. This includes digestion, absorption, and circulation; digestion, by which the food is prepared, adsorption, by which it is taken up, circulation, by which it is distributed. The other processes may be classified also in several groups. Respiration throwing off Carbonic acid, the skin throwing off vapor of water, and the kidneys the compounds into which Nitrogen and Ammonia principally enter.

The order in which I propose to take up these is a natural one, corresponding with the order of succession of events in the transit of a given particle of matter through the body. First, the introduction of the food and the changes of the food; then the process of absorption; then the process by which this material is carried to different parts of the body; then the process by which it is separated and cast off.

Digestion, though forming one of these heads, is far from being a simple process. In the Polyp nothing more is required than the introduction of the food into the stomach, where solution takes place. But in the higher orders, arrangements are made for the mechanical division of the food, and we have in place of a simple digestive sac, which exists in the Polyp, a canal so modified as to present one cavity, provided with an apparatus for mechanically dividing the food; another in which the food is digested, and another for its absorption or introduction into the vascular system.

In the present lecture, I wish to describe the organs for the mechanical division of the food, previous to its being rendered suitable for the commencement of the process of absorption or even of solution. The necessity of an apparatus for dividing the food mechanically, grows out of the condition of

the food itself, and the rapidity with which the process of solution is carried on. The Hydra swallows its prey, and a long time is required for the process of digestion. In the higher animals this process is carried on much more rapidly by the aid of an apparatus for its mechanical division. It is the same process of which the chemist would avail himself, if he wished to dissolve a certain quantity of lime in a given time. He would not throw it into the fluid, in a single mass, but would subdivide it, in order to expose additional surfaces to the action of the fluid. A single mass thrown into a fluid, is acted upon by it only on its surface. If you divide the mass in halves or quarters, the surface is still further increased, and in proportion as it is more and more divided, the solvent acts on a larger and larger surface at one and the same time.

At the commencement of the alimentary canal in the members of nearly all the animal series—there are but very few exceptions—there exists something in the form of a mechanical apparatus for dividing the substances that are to be subjected to the action of the solvent in the stomach.

You have in the Echini an apparatus almost as complicated as exists in higher animals—five teeth with a complicated series of muscles for their movement. In the higher forms, among the Articulata, Insects especially, the apparatus is constructed of a certain number of parts and after a certain general plan; it presents itself in a great variety of forms, modified according to the kind of food on which the animal subsists; and so strictly in accordance with its organization, that an Anatomist could tell, by inspection of this apparatus, to what class of insects the individual belonged, as well as the Comparative Anatomist could tell by the teeth of one of the Mammalia, its organization and place in the scale.

PLATE XXII.

Mouth of Bee.

We have here three figures, one of which (Plate XXII) represents the parts about the mouth; in which the apparatus for dividing the food consists of a pair of jaws, adapted for dividing hard substances; appended to these certain other parts, which serve as tactile organs; or (in Plate XXIII,) the same parts are modified for the collection of the Pollen of Flowers; and there is still another, where the Insect lives on the fluids of other animals, where all the parts which are represented in the former figure are so modified as to form a simple style, containing in the centre a tube for drawing up the fluid.

But it is among Vertebrated animals that we find these parts becoming more complex and presenting points of far greater interest than in lower classes.

PLATE XXIII.

Blatta.

The teeth, as they exist in higher animals, have been regarded for centuries—and they have hardly yet ceased to be regarded—as parts of the skeleton,—when in reality they are appendages to the digestive apparatus.

It is true, if you look at some of the animals you will find the teeth lodged in the jaws. But if you look at the teeth, either in the course of development or in the lower portion of the Vertebrated series, you will find instances in which they are appended merely to the membrane which lines the mouth; that it is from that membrane that they proceed. They differ from bones in being exposed on the surface. The teeth are shed entire; bones are removed particle by particle. Thus they have but little analogy to bone, but are to be regarded as more strictly analogous to the spines and scales on fishes or to the hairs and nails of the human body. And if you suppose, as it is reasonable to do, that the mucous membrane is only a modification of the skin, then the teeth become appendages to the external surface, and not a part of the internal skeleton.

In examining the teeth, the uses in connection with which they are to be taken up are quite varied. The more important one is in relation to the process of digestion. But because they are subservient to the process of digestion, it is not to be supposed that this is the only use to which they are adapted. In some animals they are used as organs of defence or attack, in others for locomotion, in others for the introduction of poison. This we shall have more fully detailed in the course of the present lecture.

PLATE XXIV.

Sec. of Human Tooth.

The first point is to determine the structure of the tooth. To get an idea of the parts which enter into its composition, (Plate XXIV.) we have here a section of a human tooth, as it appears under the microscope, and which is shown to be made up of three different ingredients; a central portion, characterized by the existence of minute canals radiating from the central or pulp cavity, and which is identical with ivory; above this, the tooth is invested with enamel forming the crown, and below, the roots are covered with a thin layer of a third substance, formed of a material, similar in its composition to bone, but which has received the name of *cementum or crusta petrosa.* Those have been noticed mainly because, in the examination of the teeth of animals, however much they may appear to deviate in their structure from that of the human body, the deviation will be found to

depend mainly upon the relative development and position of these three substances.

PLATE XXV.

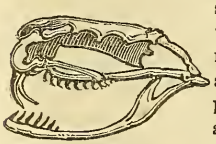
Elephant's Tooth.

In this tooth of the African Elephant, (Plate XXV,) which presents one of the extremes of deviation from the human type, the central portion is made up of ivory thrown into a series of elevated ridges invested with enamel, and the enamel in turn, concealed, except on the surface, by the *crusta petrosa*, which, instead of being confined to the roots of the teeth as in man, forms a thick layer about the crown. When the tooth has been used, the enamel being the hardest and most resisting, the other two elements are worn away more rapidly, so as to leave the first projecting in the form of ridges, and thus secure a grinding surface well adapted to the division of the kind of food on which it subsists.

In studying the teeth as they are presented in the animal series, they exist in their simplest condition in the class of *Fishes;* serving rather for seizing and retaining their prey, than for dividing its flesh. In Sharks the teeth become true cutting organs. There exist also many fishes provided with teeth at the entrance to the œsophagus, which act in the same manner as the grinders of the higher animals. In this class they are not confined to the jaws merely; but are situated on many of the other bones of the mouth, as those of the palate, vomer, &c.

In Reptiles, teeth are found in nearly all the positions in which they are seen in fishes; and for the most part, present the same simple forms, serving far more generally for prehension than for mastication. This is true of Batrachians, Serpents, and many Lizards. In the first order, they are exceedingly minute; but in the second, are far more formidable, though insufficient to act otherwise than to assist in retaining and swallowing the food. Not only are the teeth adapted for this purpose, but the jaws themselves present modifications which do not exist in any other class of animals.—

PLATE XXVI.



Head of Rattlesnake.

In this head of a Rattlesnake it will be seen that the jaws are exceedingly moveable on each other, articulated to the most posterior part of the head, and united in part by a flexible ligament, a condition of things which will allow the whole mouth to be expanded into a hoop, and thus allow the entrance of bodies many times larger than the ordinary diameter of the head. The teeth, by their recurved form, are rendered still more suitable for the peculiar use to which they are subservient in the act of swallowing. An animal on which it preys being seized, as a frog or toad, the bent teeth prevent its escaping from the mouth, and at the same time the lower jaw being carried forwards, the teeth are again inserted into the prey; and when retracted, force the food towards the œsophagus, and by repeating this operation many times, it is at last carried wholly within it.

In Birds, teeth are never developed, though their bills may be regarded as analogous to them in their action in many instances, as in the Carnivorous species, but far more generally it serves as an organ of prehension simply, taking the place of a hand, not only for seizing articles of food, but they are used in building their nests, &c.

Among Mammals the teeth acquire their most complex character, and become far more interesting, not only on account of their physiological relations, but as affording the surest indications of zoological affinities.

Three principal types of teeth exist among the members of this class, which have a special reference to the kind of food on which they exist, viz: the *Carnivorous* and *Herbivorous* groups, and a third which may be regarded as intermediate, living on a *mixed* diet.

Among *Carnivora*, the following forms of teeth are recognized as existing in all the species: 1st, teeth situated in the front of the mouth, usually six in number in each jaw, having a more or less wedged-shape, called *incisors;* 2d, a single tooth on each side in each jaw, the *canine;* 3d, a variable number of teeth, having crowns more or less modified, and denominated *molars*; and it is these last. which the zoologist regards of the highest importance, since they, being more especially designed for the division of the food, have necessarily a more obvious relation to the peculiar habits of a given animal. The incisors are of subordinate value, the act of seizing and retaining the food being performed by the canines; in fact, there are many Carnivora in which the incisors disappear at an early period of life. The canines are, in all this order, long and pointed, as shown in the skull of a lion, and still more remarkably in this extinct animal (Machairodus) allied to the lions, discovered several years since in a fossil condition in Brazil.

PLATE XXVII.

Machairodus.

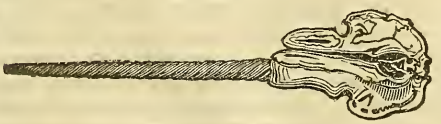
Here the canines are not only vastly elongated, but are provided with a sharp and serrated edge, forming the most formidable dental weapons, hitherto witnessed either in existing or extinct animals. The molar teeth in the order Carnivora, present a series of sharp, serrated, trenchant edges, those of the upper and lower jaw not being opposed to each other, but sliding by, like the blades of a pair of scissors, — intended rather for lacerating and tearing, than for grinding. But among the mem-

bers of this order there are transition forms, where the molar teeth become less pointed, and are arranged so that the crowns of those in the two jaws are brought more directly in opposition to each other, as is the case in the cranium of the Bear, an animal well known to live on a mixed diet. Men and Monkeys, as well as the Hog, present dental characters *intermediate* between the Carnivorous and Herbivorous groups, having neither the sharp and serrated molars of the one, nor the flattened and complex grinding surface of the latter. The teeth of Man are nearly all of equal length, and differ as regards their relative position from those of all other animals, in the fact that they form a continuous series, there being no intervals between the canines and incisors on the one side, and the molars on the other, as is the case even in the Orangs, whose teeth so nearly approximate to those of the human body. The movements of the jaws, as indicated by the form of the articulation, are intermediate between those of the two groups just referred to, being not exclusively vertical, as in the Carnivora, nor yet allowing of that degree of lateral motion which is noticeable in the Herbivora.

In the third, or *Herbivorous* group, there exists the flat and more or less complex surface of the molars, of which we have an illustration in the tooth of the Elephant, the Horse, and the Mastodon. In nearly all the members of this group, the canines are deficient, except where they exist in the males of some species, but not in the females, as is the case with the Horse, and even there being mere rudiments. Ruminating animals, such as the Ox, Deer, Antelope, Sheep, Goat, Giraffe, &c., are destitute of incisors in the upper jaw, although the food of many of them is in so many respects similar to that of the Horse, where the incisors are always present. As will be seen in the next lecture, all such animals as are destitute of under teeth, have stomachs which are very complex, while in the others they are comparatively simple.

It has already been stated, that teeth are not subservient alone to the division or even the seizing of the food or prey; they are, in many instances, destined for entirely different uses, forming organs of defence, as is the case with the incisors of the Elephant and Mastodon, which are developed into enormous curved tusks, or as is the case in the Narwhal, (Plate XXVIII) a single incisor, and that of the left side, being developed in the male

PLATE XXVIII.



Head of Narwhal.

into a long, slender and pointed tusk, that on the right being rudimentary, and never protruding through the jaw; in the female, however, neither of the tusks extend beyond the rudimentary condition; thus the developed tusk becomes a sexual characteristic. The tusks of the Walrus, are organs of defence, but assist, likewise, in its locomotion, the arms and legs of this animal being short, for the purpose of forming something analogous to fins or paddles, are insufficient to sustain its weight on the land; when the Walrus ascends a bank or a mass of floating ice, it does so in part by the aid of its tusks, which are thrust into, or hooked on to points successfully higher and higher. In the Beaver, and the same is obvious in the extinct Castoroides, (Plate XXIX) an animal closely allied to it, the incisors, two in number, are so modified as to form chisels, which not only serve for penetrating the hard shells of nuts, on which they subsist, but also for cutting wood. In them, the enamel, instead of investing the whole circumference of the tooth, exists only on the anterior edge; consequently, the posterior edge wearing away the most rapidly, leaves the former sharp and adapted for cutting.

PLATE XXIX.

Head of Castoroides.

The most remarkable deviation from the ordinary function of a tooth, is that which is presented in the venomous serpents, when it becomes an instrument most wonderfully adapted for the introduction of poison. Plate XXX represents the dissected head of a Rattlesnake; the two poison fangs, consisting of hollow tubes, with an opening at the base and the apex; on the side of the head is seen the poison gland, from which a duct passes to the opening at the base of the tooth. The gland itself is covered by a muscle, which serves to compress it when the wound is inflicted, and thus to insure the introduction of the venom.

PLATE XXX.

Dissected Head of Rattlesnake.

One other subject remains to be noticed in connection with the teeth, viz: the process of *dentition*, or shedding of the teeth, which takes place once at least in all the Vertebrates provided with these organs, though in some the process is repeated many times. Fishes and Reptiles may be said to have no permanent teeth, inasmuch as the process of shedding and renewing them goes on through the whole period of life. In looking through the class of Vertebrata, there are three modes by which the old teeth are removed and replaced by others.

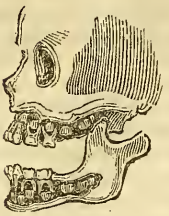
PLATE XXXI.

Jaw of a Boa.

1 We have one form in most fishes and in serpents, (see Plate, Jaw of Boa) where there exists a kind of alternation, the teeth shed having between them

others, which remain attached to the jaw until the new teeth are formed and are then dropped in their turn.

PLATE XXXII.

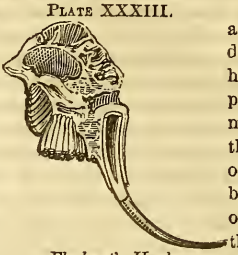


Human Head.

2. There are other animals, as is the case in some fishes, the Crocodiles and most Mammals, where the new teeth, instead of being intermediate, are developed beneath the old ones, and as they advance the fangs of the former become absorbed and the crowns drop off. We have an illustration of this mode in the human head, as shown in Plate XXXII, representing the head of a child, in which the teeth of the first set are seen in their natural position, and those of the second, as rudiments imbedded in the jaw.

3. The third form is that met with in the Elephant and Mastodon when the teeth succeed one another from *behind forwards*, as shown in Plate XXXIII, where the teeth are constantly grinding away, but are replaced by a new tooth developed behind the old one, and gradually sliding down into its place.

PLATE XXXIII.



Elephant's Head.

[Dr. W. here exhibited a diagram showing the different phases of a human tooth during the progress of its development, showing it first in the form of a papilla on the mucous membrane of the mouth, second lodged in a groove, third the edges of the groove closed over it so as to form for it a sac; from this last is to be seen an offset which forms another sac, in which the permanent tooth is developed. The remaining series of figures exhibited the completion of the first tooth, the gradual absorption of its root, and its final displacement by the permanent incisor.]

LECTURE V.

It has already been stated that the principal difference between the processes of nutrition in animals and in plants depended upon the different kind of material upon which they subsist, animals subsisting upon organic, plants upon inorganic food. Organic matter does not exist in the natural world in a state suitable to be absorbed, and in order that absorption may be effected, a preliminary process is necessary—the process of digestion. This process having been effected, the two kingdoms may be said to be more nearly alike; so that the remark of Boerhaave is not without reason, viz., that animals are similar to plants, the former having their roots within them, but the latter on their surface. It may seem that an exception exists, with regard to the statement above made, that organic matter does not exist in a state suitable for absorption, in the case of a large number of animals who derive their nourishment from other animals, that they take the fluids of other animals, and without necessarily digesting, absorb it at once into the system. This is only an apparent exception: for, though they do not digest the food themselves, this is effected by other animals; it has already been subjected to the action of the jaws and gastric fluid, and these Parasitic animals merely avail themselves of the work of another.

The mechanical means by which the subdivision of the food is effected, have already been described, —and it now only remains to speak of the rest of the apparatus which is presented to us in the intestinal canal.

Going back to the simplest condition of the digestive apparatus, we have that which exists in the Hydra, where it presents a simple sac, into which nutritive matter is introduced, and from which it is absorbed into the general system. This simple condition of a stomach has other points of interest —not merely from its being the most simple form, but also from its relation to the general surface of the body. If you commence on the outside of the body, and carry your eye to the upper extremity, and then into the stomach, you find that there is a continuity of surface, and you find that the lining of the stomach is quite similar to the external sur-

face. That these two surfaces are not only continuous, but have a strong analogy, is shown by the fact, that in these most simple animals one is capable of performing the office of the other, as has been shown by Trembley and repeated by others—that one of these surfaces may be substituted for the other, simply by turning the animal inside out. It may be done by passing a thread through it, with a knot on the end, and then turning it as you would the finger of a glove; the animal not suffering at all, and the process of digestion going on in this new cavity as well as before.

I have referred to this continuity, for the purpose of calling your attention hereafter to the similarity between the skin and the membranes, which line the general cavities in the higher series, the differences being, it is true, far greater as you ascend; but still strong points of resemblance are traceable.

Before describing the digestive apparatus, I will repeat what I have once before referred to, that in taking up any one class of organs and following it through the different groups, we are not to expect a gradual and constant approximation to the more perfect state, as we ascend. It is not by examining one class of organs that the animal is said to be superior to another, but by examining the totality of its functions. So long as a single class of organs was made the basis of classification in the series, so long errors were made; but when it was done according to Cuvier's method, by taking into consideration the whole organism, then Zoology became a science. In examining the various forms of a given class of organs, in going up in the scale, we find that they do not ascend gradually, but in a superior order they commence in a condition far below where we left off in the lower type. The eyes of some Vertebrates are far less perfectly developed than those of the Cephalopoda, or Nautilus and Cuttle-fishes, though the latter are Mollusks.

There are those in the Articulata, whose organs of motion and sense are inferior to some of the Radiata, which is a lower type. Setting aside, therefore, any attempt to find regularity, we must take some other basis of classification, derived from similarity of structure and Physiological characters.

If we pass in review the different kinds of digestive apparatus which exist in the different members of the series, we may arrange them in three groups. In the first group are included all those animals which consist of a simple sac or of several sacs united together, the individual cavities not being complete. A second group in which they have their intestinal cavity branched, extending through the body. A third group, in which there is a canal; that canal, however, divided into different sections, each one having its own peculiar function; one for the mouth; then another will serve for the process of digestion, or the solution of the food; then another, from which the process of absorption takes place.

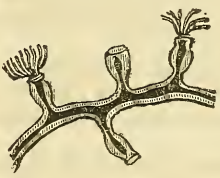
PLATE XXXIV.

Hydra.

With regard to the first kind of digestive organ, we have it in the section of Hydra, (Plate IV,) the whole animal being more perfectly represented in Plate XXXIV, where there is visible in the interior the digestive cavity. Around the mouth arms exist for the purpose of seizing its prey, which being introduced into the stomach, the solution takes place at once, without even the aid of the action of teeth, or any mechanical division whatever.

In another kind of Polyp, in one of the aggregate kind, where there are several individuals on a common stem, each one is provided with its own digestive sac; but with this complication, that there is a communication between all the sacs of the different animals; as is the case in this little

PLATE XXXV.



Campanularia.

Campanularia, (Plate XXXV) where each animal is a repetition, as it were, of the Hydra, which is represented in Pl. XXXIV. But if you trace these towards their attachment, you find a canal passing along the axis of the stem. That canal communicates with all the digestive cavities, so that any food taken in by one of the Polyps, is readily transferred along that canal to the others. Thus there is a community of digestive material in the alimentary canal of these animals; each one transfering the food it receives, to the other members attached to the common axis. This is true of many races of compound animals.

The second form of digestive organs to which I will refer, is that in which the digestive cavity is more or less branched, extending through the different portions of the body. We have an illustration of this in the common Jelly-Fish, (Plate

PLATE XXXVI.

Medusa.

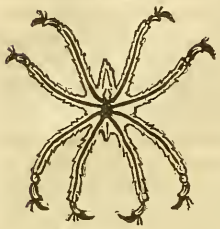
XXXVI) [The Professor also exhibited a Diagram, representing a vertical section of this animal.] In the centre is the mouth, and branching off from the two sides, are four sacs, and from each one of these sacs, there pass a series of tubes, which carry the digestive substance through the body; the tubes being mere prolongations of the stomach.

PLATE XXXVII.

Planaria

In the Planaria, (Pl. XXXVII) we have an animal analogous to the Parasitic Flukes, which inhabit the interior of other animals. In this animal, there is a central canal extending through the body, and passing off from that, different branches, which extend widely through the body.

PLATE XXXVIII.



Pycnogonum.

Here is still another, a Crustacean, (Pl. XXXVIII), with a digestive sac in the middle, and free appendages from it extending out into each of the legs, even into the bases of the jaws themselves. Now in all of these forms it would seem as if nature had first adopted a certain plan, first simply for a digestive apparatus, but had so modified it as to render it suitable for circulating the products of digestion through the body, and, as we shall see hereafter, for respiration.

The third kind of digestive apparatus includes all those animals which belong to the class of Vertebrata, and also a large portion of the Invertebrate series.

Before describing these in detail, I will ask your attention for a few minutes to some general considerations on the structure of the parts entering into the formation of the digestive canal in the higher animals. The digestive cavity is intended not only for the secretion of a fluid capable of dissolving the food, but also for conveying the food through it for the purpose of absorption. It is lined by a membrane, which may be regarded as a modification of the skin itself. I have already called your attention to the turning in of the skin over the mouth of the Hydra.

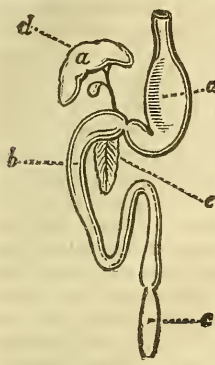
If, in the higher races, you follow the common integument from the general surface into the mouth, you will see that as it passes the lips, the skin becomes more delicate, and its vascularity also increased, and is gradually converted into the mucous membrane, which lines the mouth. In what does this change consist? The skin is made up of an external layer or scarf-skin, or cuticle; below this is a second layer, consisting of the true skin. The external layer consists of cells, which were at first spherical, but at last becoming flattened and dry from the evaporation of their contents, assume the form of scales. The second layer, which is that part which is convertible into leather, is dense and fibrous, giving the integument of the body its firmness and resistance. In passing from the outer to the inner surface, or from skin to mucous membrane, the inner, or the thicker becomes more delicate, and the outer portion, instead of being dried, retains its original character of cells filled with moisture. On making a section through the mucous membrane of a portion of the intestinal canal, you have one portion representing the true skin, and this on the outside, which is much the thickest, corresponding with the Cuticle. The only difference is, that the cells are rounded and filled with fluid. The conditions just described are such as are necessary to convert the skin from a protecting membrane, which it is externally, into an active secreting and absorbing one. It is from this membrane that all the glandular organs of the body are formed, the simplest condition of which is that in which the membrane is turned in upon itself, so as to form a pouch or sac.

The blood vessels circulate upon its walls from which the secreted fluid passes through the cells into the mucous surface. Another modification of the mucous surface, adapts it, as will be shown in the next lecture, for absorption.

One other element it will be necessary to refer to, viz: the tissue by which the motions of the contents through the digestive organs are effected, and that is a form of muscular fibre, but quite different from the muscular fibre which you have seen in a former lecture. The muscular fibres under the influence of the will are characterized by the existence of transverse lines, which are seen in Plate XXI, these lines running at right angles to the axis of the fibre. But if you look at this fibre of organic life, you will see no such marking. Further, there is not only this Anatomical difference, but there is a striking Physiological contrast. Those of animal life are easily stimulated by the influence derived from the nervous system, as well as by that of galvanism transmitted along the nerves. *These*, on the other hand, are completely removed from the influence of the will, and are not readily acted upon by a stimulus applied to the nerves going to the digestive cavity. If, however, they are stimulated directly, the irritation being applied to the fibre without traversing the nerves, contractions will take place, though of a slow and inert kind; nevertheless sufficient to keep up those peculiar movements which are necessary for exposing the contents of the digestive organs to the direct action of the secreting and absorbing surfaces. The natural stimulus to their contractions is the food contained within the digestive canal. Thus no intervention of the will is required in this part of the nutritive process, and scarcely even that of the nervous system itself.—There are still other tunics recognized in the structure of the intestinal canal, but it is unnecessary to refer to these, as they have little physiological importance. The arrangements of the muscular fibres of the human stomach represented in this diagram, (Plate XLIII,) where you have one set passing aronnd it and another parallel to its axis, these two kinds are repeated through the whole length of the intestinal canal, and are sufficient to

produce all those motions which are necessary for the transfer of food from one part of the canal to the other.

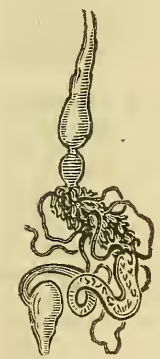
PLATE XXXIX.



Digestive Canal of a Fish.

On examining the different forms of the intestinal canal belonging to the third group, referred to above, the divisions exhibited in the accompanying figure, of the digestive canal of a Fish, are to be noticed; following the mouth and œsophagus, the stomach (*a*); succeeding this, but separated from it by a valve, the small intestine (*b*); and lastly, the large intestine, (*c*) also separated from the preceding portion by a valve. Subdivisions resembling, if not precisely similar to this, exist even among Invertebrates. Here is the intestinal canal of an Insect, (Plate XL) divided into different parts, a part corresponding to the gullet, then a second portion to the stomach, or digestive cavity and intestinal canal. In this, which is a microscopic animal, belonging to the articulated type, (Stephanoceros) there exists an apparatus for grinding up the food, situated just above the digestive cavity, almost as complex as that met with in any of the higher animals.

PLATE XL.



Intestinal Canal of an Insect.

Passing to the intestinal canal in the Vertebrata, we have the simplest form in the class of Fishes, consisting of a canal leading from the mouth into the stomach, the stomach generally curved upon itself, and (Pl. XXXIX *a*) separated from the intestines by a valve formed by the folding of the mucous membrane; and then a canal more or less convoluted upon itself, but shorter than the whole length of the body.

Besides the canal itself, there is usually superadded the two organs situated at the commencement of the intestines, which pour a secretion into its cavity for facilitating digestion. One of these organs, the liver, discharges its secretion, the bile, on one side, and the pancreas, which is the second secreting organ, on the other. In most, however, this last, instead of being a massive gland, as in sharks, exists in the form of a series of tubes, oftentimes quite numerous, but which serve the same purpose, being a more simple condition of a glandular organ.

In Reptiles the digestive organs bear a strong resemblance to those of Fishes; for, like them, they are mostly carnivorous. In Tortoises, however, which are mostly vegetable eaters, there exists a striking difference, as is the case with all vegetable eaters, compared with Carnivora, in the relative length of the intestinal canal, that always having a greater length in animals living upon vegetable substances.

In passing to Birds, we have a modification of the whole apparatus of digestion, which seems to have a relation to the peculiar kinds of locomotion; the arms being no longer subservient to taking the food; but changed to wings, they have a substitute for them in the bill, representing a hand, or perhaps more properly a thumb and finger, which they use for taking hold of objects, particularly in building their nests; and the neck seeming to take the place of an arm. In order that their motion may be effected with the greatest facility, the centre of gravity ought to be in the central space between the two points to which the wings are attached.

Now if the head should contain organs of mastication and muscles to move the jaw, there would be so much added to the weight of the body, in advance of the centre of support, and consequently bring the centre of gravity nearer the anterior portion. In order that the weight may be equalized, the organs for grinding the food are omitted in the jaws of birds, and they have as a substitute for them a gizzard, which may be regarded as a stomach, in which the muscular walls have become thickened, and their cuticle so far developed as to form grinding surfaces for acting upon the food. Thus we have an instance in the stomach of the cuticle assuming the same form and character as we have on the palm of the hand and on the sole of the foot, only it is more dense. Or in other words it is only necessary to have certain circumstances to exist in order to have mucous membrane change to skin.—But as these changes of the structure of the stomach vary in accordance with the food on which birds subsist, so as in other races you can determine the zoological relations of animals by their teeth, here you can accomplish the same purpose, though less accurately, by their stomachs or gizzards, these being modified according to their particular kind of food. We have one kind of gizzard for a vegetable diet, a second for a mixed kind of diet, and others for animal food. The purely flesh-eating bird, having a simple cavity with thin walls, the omnivorous bird having an intermediate form between the two extremes.

PLATE XLI.

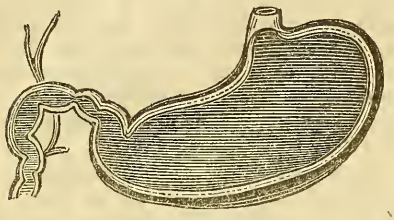
Passing from the Birds to the Mammals, we have the intestinal canal likewise modified

PLATE XLII.

Stomach of a Dog.

with reference to the particular kind of food on which they subsist. If the food be entirely of animal nature, the stomach is very simple, as in this of a carnivorous animal. (Plate XLII.) The human stomach may be cited as an example, (Plate XLIII) in which there is an elongated form, and

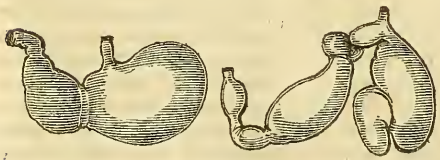
PLATE XLIII.



Human Stomach.

another (Plate XLIV,) suited to a vegetable diet and in which there is a subdivision into two cavities; one cavity, lined with cuticle, seeming to act simply as a reservoir for food, and the other is for the secretion of the gastric fluid, and for digestion. In Plate XLV, the stomach is still more complex, consisting of four cavities—the first serving for the temporary lodgment of the food, and in which it undergoes a kind of maceration; after which, the food is carried back into the mouth—is re-masticated, and thence into the second stomach, and then into the third—the functions of these two last being unknown; and finally into the fourth, which is the true digestive cavity. This presents the most complex form in which the stomach is found.

PLATE XLIV. PLATE XLV.



Stomach of a Hare. *Stomach of a Calf.*

If it be asserted that the complexity of the stomach is increased in proportion as the food assumes more and more of a vegetable character, the assertion would be too strong. There are exceptions which it is almost impossible to bring under any rule. The food of the horse and the ox differ but little, yet the stomach of the former is simple, and that of the latter quite complex. Thus the assertion cannot be regarded as precise, though the statement is correct in the main.

In attempting to determine the uses of the different parts of the intestinal canal, we have to consider, first, those changes which take place in the mouth; second, those which take place in the stomach, and third, those in the intestine. The changes in the mouth are of a mechanical nature, already described; but besides this, there is the addition of the secretion from the salivary glands. The question naturally arises, as to how far the addition of this fluid is necessary for the process of digestion. In reply, it may be stated, that there is no positive evidence that the secretion of saliva is necessary for carrying on the digestive process. In itself, it has no effect on the ordinary articles of diet. For it has been found that they undergo no more change when placed in this, than what takes place in so much water, with the exception of those articles which contain starch, which the saliva seems to convert into sugar. With regard to those animals who only bolt their food, the salivary glands are but little developed. But if an animal chews its food much, and it is dry, the salivary glands are very much developed. So that there is a constant ratio between the development of these glands and the more or less dry nature of the food on which the animals subsist.

With regard to the changes which take place in the stomach, these have always been a favorite field of enquiry among Physiologists, and have also been the source of more fruitless speculation than almost any other subject. It would seem that a process so much under the observation of all, could be determined easier than others which are further removed. But, considering the amount of attention which has been given to the subject, less positive results have been obtained than might have been expected, though some of the more important changes which take place have been determined. In examining food as it passes from the mouth, you have it more or less mechanically divided. It passes into the stomach, remains there a certain length of time, and then is dissolved. It no longer presents the characters which it had on being swallowed. You are no longer able to recognize it as it was introduced into the mouth. How is it that food, consisting of a great variety of articles, after remaining in the stomach a certain length of time, is converted into a homogeneous pulpy fluid?

It is not necessary for me to enter into the details of the various theories which have existed on this subject. I will refer to the only one recognized at the present time, as founded upon an accurate basis. And this, the explanation which dates back as far as the latter part of the last century, and which originated with Spallanzani.—Spallanzani was the first who attempted to explain this process from actual observation. Reaumer attempted to show that it was by the mechan-

ical division of the food that digestion took place, either by the teeth or by the mechanical action of the coats of the stomach.

Spallanzani commenced his observations at the same time, and saw at once the folly of Reaumer's experiments. He saw at once that the reason why the food was not dissolved when it was introduced into the stomach was, that the seeds were introduced whole, and the husks were insoluble. Accordingly, Spallanzani modified the experiments in a great variety of ways, introducing the substances into the stomachs of Birds, and allowing them to remain there a certain length of time, he proved that the solution of the food was not dependent upon the mechanical action of the stomach, but upon some other cause, supposed to be a peculiar fluid secreted by the coats of the stomach, and his next step was to obtain some of this fluid. Accordingly, he introduced into the stomachs of Birds, sponges, tied to a string, and withdrew them when they had become saturated, their contents being squeezed into a phial; and performing this operation several times, he obtained a sufficient quantity of fluid. Experimenting with this, he found that if all the conditions of temperature, subdivision, &c., were attended to, that digestion could be performed out of the stomach as well as within it.

The result was, that by experimenting with the gastric fluid thus obtained, he produced all the phenomena of digestion out of the body. He determined positively the existence and the action of this fluid, and all subsequent observers have done but little more. They have experimented in different ways, but have done little besides following in his footsteps. Some observations were made by Mr. Hunter, the celebrated English Physiologist, which are of interest, relating to the action of this fluid on the body after death. It would seem, that this fluid does not act on the tissues of living animals, otherwise the stomach itself would be digested. Parasitic animals resist its action.—Mr. Hunter observed several instances in the human body, in which the stomach was found perforated after death and the contents had escaped; and this generally in persons who had died suddenly, in good health and after a full meal. This perforation presenting on its edges all the appearance of digested tissues, he ascribed it to the action of the gastric fluid, which before death could not act upon them, but the moment life ceased, they were digested as the contents of the stomach themselves would be.

The most complete series of experiments, however, are those with which all are, perhaps, more or less familiar, performed by Dr. Beaumont, a late Surgeon in the U. S. Army, on St. Martin, an individual who had received a wound in the side of the body, and in whom the stomach communicated externally. He had received a gunshot wound in the side, which not only perforated the chest, but also the walls of the stomach; and when the process of healing was completed, there was a union between the edges of the stomach and the skin on the outside, so as to form a free communication externally. Subsequently, there was formed at the entrance, a valve, consisting of foldings of the mucous membrane of the stomach. These foldings, coming in contact with each other, acted as valves and retained the food, but allowing a thermometer or other body to be introduced, and the condition of the organ examined.

A vast number of experiments were performed on the digestibility of different kinds of articles of diet, the condition of the stomach in health and disease were determined, its temperature, motions, &c. accurately noticed. There would not be time for me to enter into the details of the results, but they are in all respects confirmatory of those of Spallanzani.

The existence of the fluid being a matter about which there can be no longer any doubt, the other conditions necessary for carrying on solution of the food, are the simple mechanical action of the parts and a certain temperature. The food being introduced, the communication between the stomach and the canal beyond (Plate XLIII, left side of the fig.) being closed by the valve, the muscular coat of the stomach begins a series of actions which give the food a progressive motion, as was noticed in St. Martin, where the food could actually be seen, the different articles passing in succession before the opening. The object of this movement is evident; it serving to bring the surface of the different substances contained in the stomach in contact with gastric fluid, which constantly secretes by the walls. After the food has been reduced to a fluid condition, when the food is digested, then the valve relaxes, and allows it to pass from the cavity of the stomach into the intestines. All the ingredients are now reduced to a condition in which the original materials cannot be detected, unless they be of an oily or fatty nature. The oily substances are merely minutely divided, but are otherwise unchanged.

Passing from the stomach, the contents undergo another change in the intestinal canal. And that is effected by two secretions, the secretion from the liver which is poured into the intestines of the human body. This tube (Plate XLIII, left end) receives the secretion from the liver. The use of these secretions is not fully understood, with regard to the process of digestion. The secretion from the liver is itself something withdrawn from the blood, which it is necessary to remove, in order to preserve the blood in a condition suitable for nourishment; and it doubtless subserves some useful end in digestion, though Physiologists are not agreed with regard to its precise use. But the pancreatic secretion has the power of converting oily substances into an emulsion. And this seems to be necessary in order that the oily matters may be taken up.

If you have a wet animal membrane, and im-

merse it in oil, the oil will not be absorbed; and an illustration of this exists in the common fat cell.—But if the oil be converted into an emulsion, then absorption may be effected. So long as the walls of the cell are wet, the oil is retained in the cavity. But the moment that the wall becomes dry, it passes through and becomes visible on the surface.

In order that the absorption of oily matters may take place, it is necessary that they be converted into an emulsion, and this may be effected, certainly out of the body, by the aid of pancreatic fluid. We have thus the food converted into a fluid; and the next step is its passage into the blood, which will be the subject of the next lecture.

LECTURE VI.

In the last lecture, evidence was adduced to show the existence of a solvent fluid, secreted by the walls of the stomach; this evidence was derived from the experiments of Spallanzani, Hunter, and the more recent observations of Dr. Beaumont. The latter had an opportunity of seeing it appear upon the surface of the mucous membrane, and was enabled to collect it and experiment upon it, both in and out of the body.

That it acted as a solvent, there was abundant evidence, and the only condition necessary for it to digest out of the body, was the existence of a temperature similar to that of the stomach, viz. one hundred degrees.

If the temperature was as low as thirty-four degrees, then artificial digestion was arrested.

The process of solution of food in the stomach was shown to be gradual, and to facilitate it certain movements existed, caused by the contraction of the muscular coat of the stomach, by which the contents of the stomach were kept constantly agitated. As fast as the food was digested, it was discharged through the passage of communication between the cavity of the stomach and the intestine, which was effected in this manner. The dissolved portion of the food accumulated towards the pyloric portion of the stomach; this was separated from the other or longer portion by a contraction of a few of the muscular fibres, the stomach being thus divided into two cavities; the one which contained the fluid then contracted, and its contents were forced past the valve into the intestines; after this, the circular fibres relaxed, and the whole stomach was thrown again into one single cavity.

All the substances are reduced to a fluid condition in the cavity of the stomach, and are changed so as to be no longer recognizable; but all fatty globules, whether in the form of butter or oil, undergo no other change than that of mechanical subdivision.

In passing from the stomach to the intestine, the whole contents of the stomach became subject to the action of new agents; one secreted from the liver, viz., the bile; another from the pancreas; both of which are discharged into the intestine near its commencement. After the admixture with these, the oil globules very soon disappear. It was supposed that the bile had the power of acting upon the fat, so as to render it capable of absorption. It has been shown, however, that the pancreatic fluid has this property of converting the oily matters into an emulsion, which makes them capable of being absorbed.

The secretion of the bile is to be regarded as a process for the removal from the blood of certain carbonized properties, which removal is necessary for maintaining the blood in a proper condition.

Thus far the fluid formed during digestion is to be regarded as being situated on the surface of the body.

It was shown in the last lecture that the mucous membrane is an extension of the skin, and all the contents of the intestine are as much upon the surface as if in contact with the skin itself.

The next stage in the progess of nutritive fluid is that process by which the dissolved fluid is introduced into the tissues of the body.

Before entering into a description of this process, I would call attention to the property which most of the tissues have of absorbing fluids; this will assist us in forming a conception of the manner in which absorption takes place. All the tissues of the body, excepting the enamel of the teeth and some of those of low organization, have the property of absorbing fluid to some degree.—If a portion of dried membrane be placed in water, it will soon recover its original flexibility and natural appearance. The presence of water in the tissues is absolutely necessary for maintaining the conditions for performing their functions in the animal economy. A large portion of the weight of the whole body is due to the water, which its tissues imbibe; if a piece of muscle be thoroughly dried, it will be found to have lost three-fourths of

its weight, and blood by the evaporation of its water is reduced to four-fifths. Blumenbach had the mummy of a Guanche, a native of the island of Teneriffe, which, although the skin was entire and all the organs still within it, from the mere evaporation of the watery fluids, was reduced to a weight not exceeding eight pounds.

The abstraction of the watery fluids is incompatible with the performance of vital processes. There exists an exception to this in some of the Infusoria, especially the Rotifers, or "Wheel Animalcules." These may be dried up without destroying their vitallty, and on moistening them with water, even after a long period, they will move about as before. This has been proved by Spallanzani, and more recently by the French Physiologists. A Wheel Animalcule, or Rotifer, was seen to become dry under the microscope, and after being laid away for several months, was replaced under the microscope,and water added; its parts became moveable, and the animal manifested all the evidences of vitality that it did before.

Different fluids are absorbed in different degrees. There is nothing which is absorbed so readily as water. Take three strips of dried bladder, place one in water, one in alcohol, and one in oil. Absorption of the fluid will take place in all. The one placed in water will acquire its flexibility again; the one in alcohol will be wetted by it, but does not recover its flexibility except in the slightest degree; and the same will be true of the one in oil One hundred grains of bladder will absorb three times its own weight of water, but less than half its own weight of alcohol.

Another peculiarity which I wish to call attention to before speaking of absorption, is that of the property which different fluids of different densities have of mixing with each other. If you place in a jar, in the lower part, a mixture of sugar and water, in the form of syrup, and if water be added carefully above this, there will be at first no mixture; the water being lightest, will float on the top. But if you allow them to remain a certain length of time, there will be a faint line between the two, the water beginning to descend, and the syrup to ascend, and at last the two will be thoroughly mixed together.

If water be placed at the bottom of the jar, and alcohol above it, or if sulphuric acid be the lower and water the upper fluid, a mixture will take place; though in all other instances, the heaviest fluid will be at the bottom. It will rise towards the surface, and the lighter liquid at the top will descend through the heavier one at the bottom: the mixture being thus effected in opposition to the law of gravitation.

If you will place between two fluids of different densities an animal membrane, the result will be more striking. You have here a glass or vessel of this form. (The Professor exhibited a glass vessel, something like an inverted tunnel.) This is filled with syrup. Into the top is inserted, through the opening, a tube, which is fitted perfectly tight. This vessel rests in a shallow dish, filled with water. Now, if this be allowed to remain a certain length of time, the syrup and water will mix together; some of the syrup passing through the bladder to the water on the outside, but more of the water will pass to the syrup on the inside. The water has a stronger attraction for the membrane than the syrup, and will be imbibed by it in larger quantities; but when it reaches the inner surface, it becomes diffused through the syrup, just as it did in the glass jar. The syrup having a feeble attraction for the membrane, passes in much smaller quantities to the outer surface, and there mingles with the water.

You have on the inside a greater density than on the outside, and the current is in a direction from the fluid which has the least density, to the fluid which is of the greatest density. [The Professor exhibited an instrument which was described by Dutrochet many years ago, and called by him the Endosmometer.] The fluid has arisen to this position (to the height of eight or ten inches), and in the course of an hour or two more would flow over the top of the tube. This would keep in operation several weeks. Indeed, it has been kept in operation four or five weeks at a time, the water flowing continually over the top. But it must be remembered that while a current exists from the water towards the syrup, there exists also a current, though a more feeble one, in the opposite direction —thus while the syrup within the vessel becomes diluted with the water which enters it from without, the water becomes sweetened by the passage of the syrup through the membrane from within. To these two currents Dutrochet gave distinct names; the inward current he denominated *endosmosis*, and the outward *exosmosis*, or *inflowing* and *outflowing* currents.

This property of the admixture of fluids, and this attraction for membranes, lies at the foundation of the explanations of the process of absorption; for absorption is regarded as a nearly identical process with that of the imbibition of fluids by membranes.

I referred to the fact, that the passage of the fluid was from the side which is least dense to that more dense; from the water which is least dense to the syrup which is more dense. This is generally true, but not so in the case of alcohol and water.—If the alcohol be placed on one side and the water on the other, the water will flow towards the alcohol, which is the least dense. This is because the water has the greatest attraction for the membrane—for it will be remembered that in alcohol, animal membrane absorbed only half, but in water three times its own weight.

To this process in the organic world, it will be necessary to refer, as it exists in the simplest Plants. These, as has already been shown, consist of single cells, each cell composed of a membranous wall, with a fluid in the interior. That

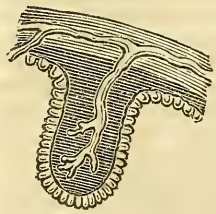
cell rapidly increases, after it is detached from its parent. How is that effected? By the absorption of the fluid by which it is surrounded; absorption taking place through the membrane, from the outer surface, towards the inner. Here absorption is carried on by the whole surface.

But if you examine a Plant more complex, there are certain parts of it to which this duty of absorption is delegated. Suppose you have a plant with leaves, a stem and roots. Absorption may take place through the roots or through the leaves, but the fluid materials are absorbed more abundantly through the roots. The absorbing portion of the root is its free extremity, or "*spongiole*," which consists of a series of cells much less flattened than those forming the cuticle of the other portions of the root; in the centre or axis of the root are the elongated cells, united end to end, forming the vessels by which the absorbed fluid is transferred to the stem, and eventually to the leaves. In plants you have the introduction of fluids by the general surface in the lower forms, and by special organs in the higher.

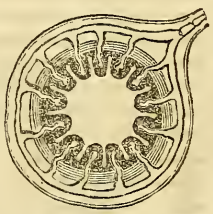
Let us look next into the animal kingdom, and see how the process is effected there. The simplest animal is the Hydra, to which we have so often referred. The stomach is regarded as a continuation of the skin, folded in upon itself. The process of absorption is effected there by the simple membranous surface, just as it is in the simplest plant, or without the aid of vessels or tubes of any kind.

But if you ascend the scale, you will find that in addition to a simple apparatus of this kind, there are some provided with vessels which ramify beneath the surface, and into which the fluid is introduced; others, in which the surface is provided with processes of a cylindrical or conical form, and these oftentimes in the higher animals existing in immense numbers; as many as 3600 have been counted on a single square inch of human intestine. They are known to anatomists by the name of *villi;* and the mucous membrane, of which they are a part, is often called the villous coat of the intestine. Each villus is invested (Plate XLVI)

PLATE XLVI. PLATE XLVII.



Villus.



Section of Intestine.

with a layer of cylindrical cells regularly disposed, and within it contains the commencement of a vessel; this vessel, however, may begin with a single or several extremities or branches; these last uniting form a trunk, which passes through the walls of the intestine to the space between the muscular and outer tunic, where it joins similar trunks from the other villi, as shown in Plate XLVII. This villus is in many respects like the spongiole of the plant. Thus you have in animals two kinds of absorbing apparatus; one by the general surface, and one by organs appropriated especially for it.

In tracing the vessel in the interior of the villus you will find that it has no communication whatever with the surface of the cavity of the intestine.

The whole process of absorption was thought formerly to be carried on by passing through open pores at the extremities of the vessels contained in the villus. But more recent investigations with the microscope show conclusively that no such communication with the surface exists. The absorbed fluid passes through these cells on the surface to the cavity of the vessel within; it does this in virtue of the very property, which I have referred to, which animal tissues have of imbibing fluids.

The vessels from the different villi uniting, form trunks, which in turn gradually unite, as shown in plate XLVIII, fig. A, and at length terminate in the large duct, which discharges its contents into the great vein near the heart.

PLATE XLVIII.

Plan of Circulation.

These vessels or lacteals are so called, because they have a milky appearance. Their discovery resulted from a casual observation. Asellius was surprised, in the dissection of a dog, to see several white lines which he had not previously noticed on the surface of the intestine. In after dissections it happened that he would not always detect them. Eventually, however, they were found to be associated with the process of digestion and were at last proved to be the vessels by which the digested fluid was carried towards the organs of circulation. When the observations were first made, in passing to their commencement, the ves-

sels were traced no further than the surface of the intestine. It is only quite recently that they have been traced down into the villi. If the villi be observed with the microscope, in persons or animals which have died when the process of digestion was going on, it is easy to demonstrate the manner in which the lacteals begin.

The lacteals have the following structure. The walls of the vessels are peculiarly thin and delicate, so thin that, unless they be distended with some opaque substance, they are nearly invisible. Their structure, however, is somewhat complex. The knotted appearance which they present externally, results from the existence of valves, which are quite numerous, and formed by semi-circular folds of the lining membrane, as shown in Plate XLIX.; arranged in pairs, and their edges coming together, so as to prevent the flow of the fluid, except in one direction; that is towards the vascular system. The bodies called ganglia, or knots, which are developed on the lacteals, so far as their structure is known, are supposed to be made up of a series of convolutions of the lacteals upon each other. The contents of the lacteals pass through these ganglia, as will be shown hereafter, and undergo an important change.

PLATE XLIX.

Valves of a Lacteal.

In passing from the digestive towards the vascular system, it will be seen that the trunk (see Pl. XLVIII) formed by the union of all the lacteals, is joined by another trunk from the general circulation. This trunk has a structure similar to that of the lacteals, but is connected, however, with a process which takes place in the tissues of the body, which I shall have occasion to refer to in the next lecture.

The vessel formed by the union of these two trunks, viz., the lacteal and lymphatic, discharges its contents into a great vein just before it reaches the heart.

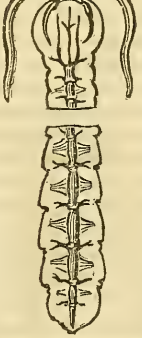
With regard to the passage of the fluid through these vessels, the question may arise as to the cause which propels the chyle through the lacteals.—You may look in three directions to discover this—the heart itself, the walls of the vessels, and to some force at the commencement of them in the intestinal canal. That the heart itself can have no action on the movement of the fluid in these vessels, is evident; since such an effect could not be produced unless you can suppose that the heart exerts a suction power, of which there is no evidence. The walls of the vessel itself are not contractile. They have been seen under the microscope in the living animal, but their size is uniform, unless some external stimulus be applied. So that you must go still further back than this. If the vessel be divided, no matter how near to its origin, you will find that the fluid will constantly flow out. You have only to recall to your mind, the conditions of the ascent of the sap in plants, and you have an explanation of the motion which takes place in lacteals.

If a tree or a plant be divided in the middle, and the upper portion of it be immersed in a vessel of water, the process of absorption will continue to go on, as will be found by the evaporation from the leaves. But if the roots of the lower portion be immersed, the fluid will rise and make its appearance on the cut end.

There are therefore two sources of motion, one derived from the leaves, and the other from the roots. The existence of this last cause of motion was demonstrated by Dutrochet, who, cutting off the trunk of a plant and finding that there was still a flow of fluid through it, continued to make sections lower and lower down; but so long as the extremity of a root remained, the fluid was still found to flow. That this force, originating in the roots, is sufficient to circulate fluid towards the leaves, is obvious from the experiment of Hales, who proved by tying a glass tube to the cut end of a grape vine, that it would support a quantity of Mercury equal to forty-three feet of water—exerting a pressure greater than that of a single atmosphere. A force similar in character is exerted by the villus of the intestine, but a comparatively slight one would be necessary to carry the fluid a distance of a few feet from the intestine towards the heart.

You have next to ascertain how the fluid is distributed to different parts of the body. And this brings us to the vascular system, properly speaking. Where no vascular system exists, the nutritive fluid is distributed by imbibition. The simplest form of a vascular system is that which exists in many insects—consisting of a contractile vessel, seeming to fulfil no other end than that of keeping the fluids in a state of agitation. The heart consists of a long pulsating vessel, as shown in Plate L, extending the length of the body, but perforated at the sides by numerous openings at regular intervals, (Plate LI). Attached to this vessel there are muscular bands on each side, which have the power of pulling its walls apart and dilating its cavity; at each opening there is a pair of valves which allow the blood to flow in, but not to escape in the opposite direction—at the head, this vessel, which is called the dorsal vessel, divides into two branches which descend on each side, then uniting form a long trunk on the underside of the body (Plate LII)

PLATE L.



Vessel of Scolopendra.

PLATE LI.

Vessel of Scolopendra.

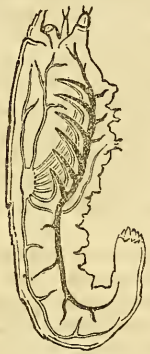
PLATE LII.

Vessel of Scolopendra.

which joins the upper trunk at the posterior part of the body. The fluid circulates in the upper vessel towards the head, in the lower in the opposite direction. As it moves, it either escapes by open mouths, or what is more probable, by passing through the substance of the walls into the tissues, where it is no longer confined to any definite cavity. Flowing freely among them, it finds its way back into the cavity of the vessel, at each dilatation, through the lateral openings above described.

In the Lobster, as shown in Plate LIII, the organs of circulation are more complete, and are provided with a central pulsating heart—circulating blood to different parts of the body after it has passed the respiratory apparatus.

PLATE LIII.



Lobster.

But in a still more advanced condition of the organs of circulation, you have a series of vessels, forming the closed circuit in which there exists no entrance other than that through the absorbing surface, and the blood is kept constantly in motion through a definite channel. Such a circulation consists of a series of vessels which distribute blood to the different parts of the body, and others which return it thence to the heart. The pulsating part is reduced to a very small compass, as shown in the Cuttle-Fish (Plate LIV), where you have the heart in the centre, and from which vessels (arteries) pass to the different portions of the body; and by another series (veins) is brought back to the organs of respiration, through which it passes, and from thence back to the heart, to commence the circuit anew. The heart, in all this race, including Snails, Slugs, Muscles, and similar animals, consists of two cavities, one of which receives the blood from the lungs or gills, and then transmits it to a second cavity, which forces it through the body. In the Cuttle-Fishes, however, there are two additional cavities for forcing the blood through the organs of respiration; but these are not very remarkably developed.

PLATE LIV.

Circulation of a Cuttle Fish.

The simplest heart which we have, then, consists of a double muscular sac. On looking at it within, to ascertain its structure, the first portion, which is called the auricle, is always separated from the second by a valve, which will prevent the blood from passing back when it has once entered the second, or ventricle, from which it is sent to all parts of the body. The heart of Mollusks being so situated as to circulate the blood through the general tissues of the body first, is called a systematic heart.

In fishes, where there is the same general plan, the heart, instead of sending the blood first thro' the general system, circulates it through the organs of respiration. You have here (Plate LV) the heart with its first and second cavity, then a blood-vessel passing towards the gills, and after passing through the gills, it reaches the main artery, by the branches of which the blood is distributed to all the organs, and then returns to the auricle from whence it started. In this case the heart occupies the opposite condition from what it does in the Mollusks; it is branchial, or gill. In the Mollusks it circulates through the body first, then through the organs of respiration; but in fishes it passes through the organs of respiration first, then through the body. But in both cases there is but a single cavity for the reception, and a single one for the discharge of the blood.

PLATE LV.

Circulation of a Carp.

PLATE LVI.

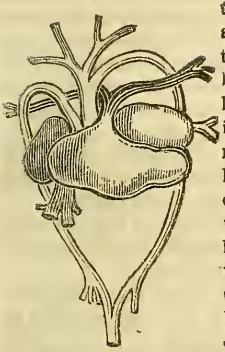
Heart of Trout.

PLATE LVII.

Heart of Gar.

The two cavities of the heart of a Fish are shown in Plate LVI, the heart of a Trout, and in Plate LVII, the exterior of the heart of a Gar Pike. The heart of a Reptile, (Pl. LVIII) is more complex; there are two cavities above (auricles), one receiving the blood from the veins of the general circulation, and the other receiving it from the organs of respiration. Thus you have in one auricle the venous blood; and in the other arterial, the blood from the organs of respiration. From both of these cavi-

PLATE LVIII.

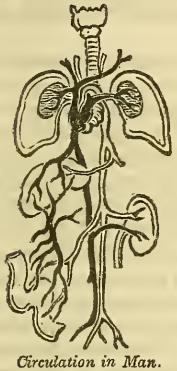


Heart and Vessels of Tortoise.

ties the blood passes into a single ventricle, and thence around the body by one vessel, and to the lungs by another. There is therefore a constant mixture of blood which has been exposed to the organs of respiration, with that which has not been, a condition somewhat inferior to that of the Fish, where all the blood goes through these organs.

Passing still higher, we come to the form of circulation which exists in the warm blooded animals, viz, Mammals and Birds, where the heart consists of four cavities, and all the blood passes through the lungs. The auricle on the right side receives the blood from the general system and forces it into the ventricle; from this the blood passes into an artery which carries all the blood to the organs of respiration.

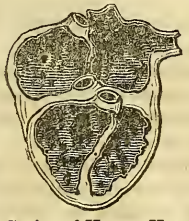
PLATE LIX.



Circulation in Man.

After the blood has passed through the organs of respiration in the warm-blooded animals, it passes through several veins to the auricle, on the left side; thence to the ventricle on the same side; and from that to the general circulation. This will be better understood by reference to Plate XLVIII B, where the circulation of the blood passes through a double series of ventricles and auricles; which represents the circulation of a warm-blooded animal, the two sides of the heart having been separated, having between them the circulations of the lungs above, and of the system below.

PLATE LX.

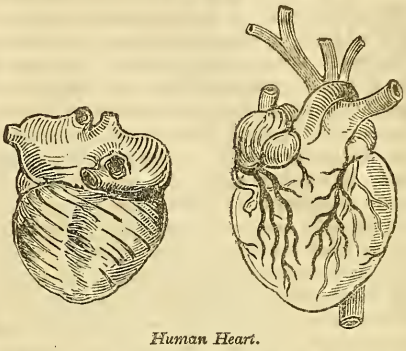


Section of Human Heart.

The internal structure of the heart in man is shown in Plate LX, representing a section of the human heart. The auricle on the right side receives the venous blood and the auricle on the left side receives the blood from the lungs; the two ventricles below receive blood from their respective auricles.

Plate LXI represents the muscular structure of the heart, which may be regarded as a series of muscular bags or sacs, each cavity being provided with its own set of muscular fibres, so arranged as to have a spiral direction both from the point towards the base and from side to side.

PLATE LXI.



Human Heart.

Now to regulate the direction of the blood, we have added to the auricles a series of membranous valves, (Plate LXII) each retained in its proper place, by the tendons passing from its free edge to the walls of the heart. Between the auricle and the ventricle, on the right side, there are three of these valves, and on the left side there are but two.

PLATE LXII.

Valves of Ventricles

If this provision did not exist to prevent the blood from regurgitating, it would be continually flowing back at every contraction of the ventricle.

PLATE LXIII.

Valves of Aorta.

At the base of the great artery which is distributed to the lungs, and the one which goes to the general circulation, there exist three other valves of a more regular form, each forming one third of a circle, as shown in Plate LXIII. These allow the transit of the blood into the vessel, but prevent its passage back to the heart.

I intended to have said something about the forces which circulate the blood, but as the hour is so nearly elapsed, I shall defer that for the commencement of the next lecture.

LECTURE VII.

In the last lecture I described the organs by which the blood is carried through the different parts of the body. In the muscular system of the simplest form, of which we have an illustration in the insects, there existed simply a pulsating organ or vessel extending along the length of the back, and another along the under side, and through the walls of these the blood passes, by transudation, and is distributed through the different systems. In the class above this, the Mollusks, the organs become quite perfect; there being a heart provided with two cavities, an auricle and a ventricle, the blood passing from the auricle to the ventricle, from thence through the body by arteries, and then by the veins through the lungs. In Fishes the same arrangements exist, with this difference, that the heart circulates the blood, first through the gills or organs of respiration, and subsequently, through the general circulation.

Among the Reptiles we have an advance in the structure of the heart, and instead of being composed of two cavities, as in the Mollusks, it consists of three. Instead of a single cavity for the reception of the blood there are two, viz. a right and left auricle, and below, there is a single cavity or ventricle in connection with them, the blood from the organs of respiration being received in one auricle, and in the other, the blood from the general circulation; thus their respective contents passing to one common ventricle are there mixed together.

From that ventricle there issue two arteries, one to the lungs and one to the general circulation, so that you have the two kinds of blood circulated through the body.

This is necessarily an imperfect circulation. But there exists an approximation in Reptiles to that which exists in the higher order of animals.

In the higher species, the blood coming from the cavities on the two sides is kept in part distinct, and in the Crocodiles there is a separation between the two ventricles, though there is a slight communication at the bases of the great arteries; so that the circulation is nearly complete, but never acquiring that completeness which it does in the Mammals and Birds, where all the blood has to pass through the right side of the heart and the lungs before it can come to the left.

Having spoken of the organs through which the blood flows, there remain yet for consideration the forces by which the blood is driven through the vascular system, as well as the phenomena of circulation itself.

First, with regard to the forces.

As to the cause of the circulation of fluids through the lacteals, as shown in the previous lecture, there is no difficulty; for in them you have a power of imbibition sufficient to carry all the chyle through the lacteals into the venous system.

With regard to the main force by which the blood is carried through the vascular system, it is very clear that it comes from the heart.

But to determine *all* the forces is no easy matter, and this determination has been an object of speculation among Physiologists for a long time, and still continues to be.

The only way to explain clearly what is known, is to consider, first the heart, then the vessels, and their respective uses in, and influences upon the function of circulation.

In order to determine the forces with which the heart acts, a variety of experiments have been made, and scarcely any more satisfactory than those of Hales. I refer to his experiments where he tied a tube on the top of a grape vine, to determine the ascending force of the sap, and found, as indicated by the column which it would sustain, that it was greater than the weight of the atmosphere. In experimenting upon animals, for the purpose of determining the pressure of the heart on the blood in the arteries, he introduced into an artery a tube, and measured the distance to which the blood rose in the tube. The column thus sustained would be the exact measure of the force with which the blood was propelled through the vessels.

Of course no experiment of the kind can be performed upon the arteries of the human body. With regard to the force of the human heart, there could be nothing more than an estimate made, and that rather a rude one. But Hales, after comparing the heart in man with that of different animals, and the columns which they would sustain, was led to this result:

That the pressure the heart exercised would be about equal to four pounds and six ounces.

It was objected to this, that the tube would cause the blood to coagulate very soon, so as to prevent its easy flow, and thus interfere with the level which it attained being an exact index.

A French physiologist, Poiseuille, has used an instrument of a different form—an inverted syphon, instead of a tube—one end of which was drawn to a point, and was arranged so that it could be readily inserted into an artery, which was secured around it by a thread. In this tube was a column of mercury, and between the mercury and the blood, an alkaline solution, for the purpose of retarding the coagulation, and thus preventing, as far as possible, any inaccuracy which might arise from that source.

It was found by the experiments of this Physio-

logist, that the estimated column of blood in a man's body, following the same rules that Hales had done, was equal to four pounds and three ounces. Thus, following a different method, and by an independent series of experiments, he arrived at nearly the same results.

The question arises, whether the force of four pounds three ounces is sufficient to propel the blood over all parts of the body.

You have the blood circulating through the vessels of every variety of size, from those which have a diameter of a little more than an inch, to those not exceeding a 3-1000 of an inch.

It has always been contended by those who have discussed this point, that the friction which would be caused by the transit of the blood, would counteract all the force of the heart.

To show that this opinion does not rest on a firm basis, the experiments which have been performed in the bodies of animals recently killed, as well as in the human body, are sufficient to show that a very small force is sufficient to carry the blood through the whole vascular system.

D. Sharpey forced fluid through the vessels of an animal by using a syringe under a pressure equal to that of the heart, which caused the blood to pass through all the vessels, the veins included. This experiment has been made, not only with water, but with blood from an animal just killed.

A force equal to four pounds and three ounces, is therefore sufficient to force the blood through the arteries and cause it to return through the veins to the opposite side of the heart.

It is a matter of some interest to determine the time required for circulating the blood through the whole system. The ordinary mode of calculating this, though not to be relied upon as accurate, is as follows: First, to ascertain the full amount of blood in the body; second, the capacity of the left ventricle of the heart; and lastly, the number of pulsations or discharges of blood per minute.—With regard to the whole amount of blood in the body, this can only be an imperfect estimate, because it is impossible to collect *all* the blood, so that you can make an exact measurement.

But still an approximation to the truth doubtless exists, for in instances where persons have been guillotined, where the blood was instantly poured out, as many as twenty-five pounds of blood have been collected, so that this will certainly not be too low an estimate for the amount of blood in actual circulation; and on making proper allowance for that which would be left behind, it is estimated that the whole amount would not be far from thirty pounds; or, to give it in the precise numbers, twenty-eight pounds, for a person of average size, as stated by several Physiologists.

If this be the amount circulating in the body, we have next to ascertain what quantity of blood is sent out at each pulsation of the heart. For if this is ascertained, we can readily determine how long it would take for the whole amount of blood in the body to pass through the heart.

The left ventricle of the heart is estimated to hold two ounces of blood. But it is not precisely certain that the whole quantity contained is discharged at each contraction. But on the supposition that the whole quantity is discharged at each contraction, and with 75 pulsations in a minute, which is the average number, we should have the time for the passage of the 28 pounds through the heart, equal to three minutes.

There is, however, a fallacy in this statement, as a simple inspection of the diagram will show. The estimate just made, goes on the supposition that none of the blood passes through the heart a second time till the whole of the blood has completed the circuit. But if you look at this diagram (Plate LIX) you perceive that a certain quantity of blood will pass through the vessel which carries it through the liver, and here another portion of blood will pass through a vessel further from the heart, which carries it through the kidney, and here, still lower down, another portion will pass through the more distant parts of the body—the lower extremities.

Now it is perfectly clear, that a part of the blood will pass through the shorter circulation of the liver, before another portion passes through the lower parts of the body, or the extremities of the toes. The blood, for example, which nourishes the heart, will pass through to the veins before that which passes through the head or the tips of the fingers, or the more more distant parts of the toes. So that such an estimate is worth very little, though it is much relied upon in determining the time for the transit of the blood through the body. Among the more obvious phenomena attributable to the action of the heart, is the *pulse*, caused by the impulse of the blood sent from the ventricle at each contraction. That the pulse depends entirely upon the heart is obvious, from the simple experiment of applying pressure upon a vessel, which, in propertion to its strength, will impede or cut off all pulsation beyond the point upon which it is made. Even after death, a simple impulse given from the syringe when it is placed in the artery, will cause all the sensation to the finger of the pulse. The connection of the artery of a dead animal with that of a living one, as in the experiment of Bichat, will cause the pulse in the dead body as distinctly as in the living one.

Before inquiring into the agency of the arteries in forcing the blood, a few words must be said with regard to their structure. The arteries being under much stronger pressure than the veins, are made much more powerful, in order to resist the action of that portion of the heart with which they are connected. That portion of the heart which circulates the blood through the lungs alone, is quite thin and feeble, compared with that which circulates through the whole system—there being an exact proportion between the labor done, and the means by which it is accomplished.

The arteries are made up of the following parts.

There is for every artery, externally, a resisting coat, which is made up of fibres interlaced with one another, so as to form a network, and give it resistance, the fibres themselves being absolutely inelastic. They are arranged, however, in meshes, so that by changing the form of the meshes. the diameter of the vessel may be increased or diminished. There is a second tunic, or coat, which is the thickest of all, and is made up of fibres which are elastic, similar to the elastic ligaments met with in the vertebral column. These occupy the space just within the outer coat. There is still another tunic, which has been discovered more recently, though suspected by Hunter, made up of muscular fibres of organic life, similar to those in the intestinal canal. And within this, is the delicate membrane which lines the cavity of the artery, a true serous membrane, and similar to the membrane which lines all the close cavities of the body.

With regard to the use of these different parts—the external coat gives to the artery its resistance to the pressure from within. The elastic coat seems to serve a very important end in *equalizing* the flow of blood through the different parts of the body. If the heart impelled its blood into tubes which were perfectly inelastic, like metallic tubes, then with every impulse of the heart, for every ounce which entered the tube, a corresponding quantity must escape at the opposite end, and that by a jerk corresponding with the impulse by which it enters. It would be the same in a common force pump, or fire engine, without an air-chamber to equalize its flow.

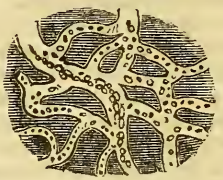
The heart acts only when it contracts; consequently, during the intervals between the contractions, unless some provision existed to counteract it, while the heart dilated, the blood would cease to move. To prevent this stagnation in the blood-current under these circumstances, is precisely the object of the elastic tunic. When the ventricle contracts and forces its two ounces of blood into the artery, the elastic tunic yields under the increased pressure and is dilated; but when the pressure of the ventricle ceases, then the elasticity comes into play, continues to act upon the blood until the ventricle again contracts, to force in a new quantity.

If an artery be examined in the web of a frog's foot, it does not appear that it contracts and dilates except as it is acted upon by the blood forced into it from the heart. In all the larger arteries there is a slight dilatation, and then at the intervals of contraction the elastic tissue acts upon the blood. The arteries, however, are found to vary in size, from time to time, and this deviation being in exact accordance with the demand for blood in the parts to which they are distributed. If the function of an organ be active, the arteries have a different size from what they have when it is at rest. More blood circulates through a gland when the process of secretion is rapid, or through a muscle when actively employed, or through the brain when excited, than when the reverse condition exists.

To *regulate* the size of a vessel in accordance with the amount of fluid sent to the different parts, appears to be the function of the muscular coat; with this provision, the arterial system becomes the same as the pipes which distribute water in a large city would be, if they had the power of adapting their size to the varying demand upon them in different quarters.

In passing towards the termination of the arteries we find them diminishing in size, and finally terminating in a series of vessels which are between them and the veins. Vessels of this class are called capillaries. If an artery (as in Plate LXIV) be examined, it will be found to consist of trunks which gradually diminish in size, but after a certain time they form a net-work, where all the vessels are of nearly the same calibre throughout, as shown in Plate LXV, a magnified view of the

PLATE LXIV. PLATE LXV.



Artery Magnified. *Capillaries.*

same. Wherever anything like nutrition or secretion or any vital process is going on, there these vessels are found to exist in great numbers, the smallest of them not exceeding the 3-1000 of an inch in diameter, varying however, in number and in the size of the meshes which they form, according to the nature of the tissue in which they exist.

The walls of this class of vessels are so thin, that they are barely perceptible with the aid of the best microscope. Nothing like muscular fibre can be seen in them, although its existence may be inferred from the fact that they have the power of changing their size. The blood, as seen under the microscope, passes through them in a continuous and uninterrupted stream. If, however, the vessels be irritated by mechanical means, they may be seen then to change their diameter, and a similar change is noticed in certain morbid conditions, as in inflammation. Then the vessels vary from their usual size; but in the *ordinary* transmission of blood through them, they undergo no change.

They do not contract as the heart does. But they are endowed with the same power which the arteries have, of regulating their diameter in accordance with the demand for nutritive fluid in different parts of the body. They are *regulators*, then, of the flow, but not propellers, of the nutritive fluid. With regard to the circulation through the veins, very little need be said, for no one can raise any

question with regard to their being almost passive in the circulation of the blood. They are very delicate. They are under very slight pressure.—They have a capacity of twice that of the arteries, so that the blood passes much more slowly through them. By whatever force the blood is propelled through the veins, it is not an intrinsic one, and there is little reason to doubt that it is derived almost solely from the heart itself.

The next subject which presents itself for our consideration is the fluid which circulates through the vascular system. I have already spoken of the chyle which passes through the Lacteals, which at the time it reaches these vessels is almost transparent, and is found to be of the same composition as Albumen, or the white of an egg. But as it passes through the lacteal system, it begins to assume the peculiarities of blood itself, especially as it passes through these ganglia seen in Plate XLVIII, when, if allowed to stand, it is found to coagulate spontaneously, and if examined under the microscope, it is found to contain slightly granulated corpuscles. These seem to be made up of an external sac, or envelope,filled with small granules, which project from the surface and give it a mulberry shape. This change which takes place in the Lacteals I will especially call attention to, because it is one of the important changes which food undergoes in the course of the formation of the blood. When the fluid enters the Lacteals, it has nearly all the properties of Albumen; but as it passes on, besides having corpuscles developed in it, it has the power of coagulating spontaneously.

Nutritive fluid, in a state of complete elaboration, exists in the blood; of the general composition of which I would next speak. If blood be drawn from the Vertebrated animals, and even from some of the Invertebrated animals, and allowed to stand for a sufficient length of time, it coagulates spontaneously, and eventually separates into two portions, viz: the coagulum, called the *crassamentum*, and the fluid in which it floats, the *serum*. If you examine the coagulated portion, it will be found to consist of a substance called fibrine, and of a series of minute bodies which give color to the blood, and which have usually been called, though incorrectly, *blood globules*, but which are, in reality, flattened bodies,like a piece of money, and are more properly called "*blood discs*." Now, if you examine the fluid portion, and subject it to the action of heat—boil it for a short time—it will soon become turbid with flocculi, which form a coagulated mass, sinking to the bottom. This is albumen, and has the same properties as albumen which is found in the egg; which, when exposed to a temperature of about 160 degrees, coagulates.

In addition to these, there exist certain other substances, such as fatty matters; also soda, potash, lime and magnesia, mineral ingredients held in solution. According to the best analyses which have been made, the composition of the blood is as follows: 1000 parts consist of

Water	784 00
Red corpuscles, or blood-discs	131 00
Albumen	70 00
Inorganic matters—soda, potash, lime, magnesia	6 03
Fatty substances	6 77
Fibrine	2.20
	1000 00

In studying the nature of these different ingredients, in relation to the processes of nutrition, albumen seems to be the most important of all. For it is from this that everything in the body can be produced.

Leaving the blood for a moment, suppose you proceed to an analysis of the different tissues of the body. The organs may be separated into tissues, and the tissues may be separated into organic elements, which are the most simple forms in which organic matter exists in living bodies. In studying these organic elements, there are found to be three groups: one of them is entirely *destitute of Nitrogen*, and contains all those substances which are made up of oil—the fatty matters of the body. There is another, called the *Gelatinous* group, which is made up of Gelatine, which is obtainable principally from the bone, from the tendons, from the cartilages and from the ligaments—from a class of tissues which are of a low degree of organization—which are not active, but merely passive in the body. The third group is denominated the *Albuminous* group, into which albumen enters largely; and these are the active organs of the body, especially the brain and the muscular system; though the latter consists principally of Fibrine; yet this is to be regarded chemically as another form of albumen. You have, then, in the general system the tissues resolvable into these three classes of substances, and all of them derivable from the blood, excepting one, and that is gelatine. No chemist has ever yet obtained gelatine from the circulating fluid. It is something which is formed from that fluid, after it leaves the circulating vessels.

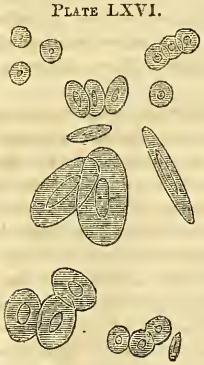
It is a matter of some practical importance in determining this fact, that a certain class of tissues are formed from this, for it seems to explain the observation of Magendie, that gelatine itself is incapable of nourishing the body. Several years since it was attempted to feed the poor of Paris on soups, soups of which gelatine was the principal ingredient. It was found after a time, that they became disgusted with it and would not even come for it. The French Academy had a committee appointed to investigate into the subject. Magendie performed various experiments on different animals, and it was found that unless provided with some other article of diet than gelatine, they died after a few weeks, of starvation, It would seem highly probable that gelatine nourishes only the gelatinous tissues, such as bone, ligament, tendon, &c., but cannot nourish the organs of active life—cannot nourish the brain, or the muscular system. So that diet must consist of something

else besides gelatine, in order to carry on the vital processes.

But all the other parts exist already in the blood, and they are formed from the albumen. But it is not necessary to go to the tissues and determine this by chemical analysis. Nature proves this almost daily under the eyes of all. You have an egg, made up of the yolk, in the centre, consisting of its yellow, oily fluid, floating in albumen; around that, the albumen pure, forming the *white*. You subject that to the heat of 100° for three weeks. Instead of albumen, you find, at the end of this time, bones, cartilages, muscles, &c. Yet no new materials have been added. The egg contains a store of albumen, which is used up gradually in the formation of the tissues, without being replaced. In the adult body, the albumen, with which there is a mixture of oil, is constantly formed out of the food taken into the body, is converted into blood, and gradually metamorphosed into the different tissues.

I have said nothing thus far of another ingredient in the blood of the animal, viz: the *blood discs;* and to these I shall only make general reference; for their precise use in the body has not yet been determined. In the blood of all the Vertebrated animals, and of many, if not all of the Invertebrated, there are seen particles floating in it, varying, however, much in size in the different races. In the human body they consist not of blood globules, as they have usually been called, but of *blood discs*. They were originally described as globules, because they were examined in water. The blood was diluted with water, and the addition of water converts the blood discs into spheres, it being imbibed by the membrane which forms the wall of the disc.

PLATE LXVI.

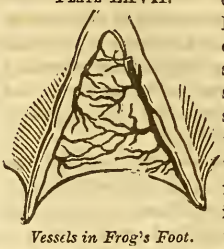


Blood Discs, of various Vertebrates.

The blood discs of the human body have a diameter of the 3000th part of an inch. In all the mammiferous animals, the blood discs have the same circular form, although they vary in their diameter. There is an exception to this in the Camel and Lama of Peru, where their form is oval, as it is in Birds, Reptiles, and most Fishes. The largest discs, which are known to exist, are those of the Reptiles, and especially of the Proteus (Plate LXVI), which have the diameter of 400th of an inch.

With regard to their uses, I have already stated that little is known. This fact has been determined with regard to them—that they have nothing to do directly with the process of nutrition.—They never leave the blood vessels, as may be shown by examining under the microscope the vessels in the web of a frog's foot, (Plate LXVII) or in the wing of a Bat. In studying their development, the later researches of the microscopists seem to demonstrate that they are developed from the globules which are seen to make their appearance in the chyle while still in the lacteals, which globules are ultimately changed into discs.

PLATE LXVII.



Vessels in Frog's Foot.

We have one step further to go in the process of nutrition—not to attempt to describe the manner in which nutrition is performed, but only to point out the course which the nutritive particles take in replacing those which have fulfilled their functions and have been cast off. The vascular system is a closed system of vessels. There are no mouths—no open orifices whatever. We have seen already at its commencement, that the fluid is not taken up from the intestine by open mouths, as was formerly supposed, but is absorbed by imbibition through the tissues. In passing to the other extreme of the blood vessels—to the capillary system—we have no open mouths, through which the blood is poured out, but yet it does escape, and that by a process similar to the one by which it entered, by passing through the walls of the vessel.

In looking at Plate LXIV, we see that there are interspaces between the capillaries, leaving little islands surrounded by blood vessels; and wherever we look, no matter how vascular the tissue may be, there are these islands, in which no blood vessels can be detected. The blood vessels form, in all cases, a net-work between the different fibres, but never enter them. The process of nutrition is effected by the transudation of the fluid portion of the blood through the walls of the vessel, and which Dutrochet has denominated "*Exosmosis*," or the "*out flowing current*." The serum of the blood, or that portion which contains the nutritive matter, as albumen, fibrine,&c., passes through, forming muscular fibre in one part of the body, nervous fibre in another, bones, or whatever the particular tissue may be, in another. But can we go farther than this, and determine *how* the tissues are nourished—how the fluid is converted into fibres of various kinds—how the renovation of a given tissue in the body is effected?—We know perfectly well how the tissues were formed originally in the egg; and that is, by first forming the nucleated cell, and its gradual transformation into other cells, and these, in turn, into the various tissues of the body. But after the tissues are all formed, the process of disintegration is going on continually, and the process of renovation as constantly. All that is known, however, is, that the blood passes through the walls

and becomes converted by some process which has, as yet, escaped detection, into the different parts of the body.

There is no evidence that the cell-process takes place in the renovation of the tissues, or that the reproduction of cells is in any way necessary in maintaining the integrity of a given tissue.

Having spoken of the nutritive fluid, of its formation, of its distribution through the body, and of the manner, as far as is known, in which it is imparted to the different tissues, we have next to speak of another class of functions—those which are subservient to the separation from that fluid of the different substances which are no longer useful to the animal economy. The most important of these processes is that of respiration, to which I will next call your attention.

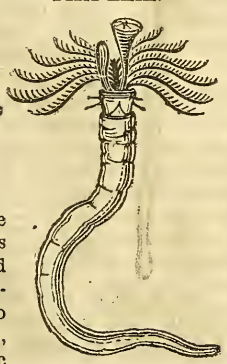
Respiration in animals may be defined to be that process, by which an interchange of elements is effected, between the blood on the one hand, and the atmosphere on the other; the blood giving to the atmosphere carbonic acid, and water in the form of vapor, and receiving from the atmosphere a portion of its oxygen. A process not unlike this takes place even in plants. The organs by which this process is effected, like all other systems of organs, will vary in different animals, according to the variations in their conditions of existence. The simple exposure of the surface of a jelly-fish or polyp to the action of the fluid around it, is sufficient to carry on all the changes which take place in its simple kind of respiration. But as you ascend in the series, instead of this being carried on by the whole surface, there are certain parts set apart for the especial purpose of respiration.

In classifying the organs of respiration physiologically, we may place them in two primary groups, those in which respiration takes place in the *air*, and those where it takes place in the *water*, varying in the two groups, however, according, as there is one or another portion of the series examined. We have an illustration of this in the fringes (Plate LXVIII) on the back of Doris, or in the

PLATE LXVIII.

Doris.

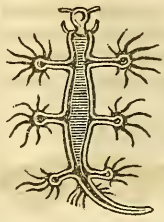
PLATE LXIX.



Serpula.

worm-like animal (Plate LXIX) which inhabits a calcareous tube, and through these the circulating fluid is exposed to the air. In the Glaucus, (Plate LXX), an oceanic Mollusk — the fringes serve not only as organs of respiration, but become also the fringes by which it swims. In regard to the water breathing animals, the respiratory organs consist of a series of fringes, or plates formed from the general surface of the body and projecting from it, though sometimes more or less protected. In these two instances, in the Cuttle-fish (Plate LIV) or in the Crab (Plate LXXI) the organs have the same general structure, but are lodged in cavities, by which they are more or less protected. In Fishes, the whole apparatus becomes somewhat more complex, where there exists a series of arches attached to the head, each arch provided with a vast number of thin elongated plates, which collectively form a fringe; each arch is provided with an artery, which contains the blood carried from the general circulation, and charged with an excess of carbonic acid. It sends off branches which terminate in a capillary net-work, on the little fibres of which the gills are made up; circulating across these, the blood becomes exposed to the action of the air; and then, passing into another vessel, the dorsal artery, it is distributed around the body.

PLATE LXX.



Glaucus.

PLATE LXXI.

Gills of Crab.

Among the members of the class of Fishes, we have one deviation from the usual type represented here (Plate LXXII), where the fish has the habit of leaving the water. The animal, crawling on the surface some distance from the water, is provided, in addition to the gill, with a cavity on the side of the head, where there is a large respiratory surface, and surrounded by a pouch capable of lodging a certain quantity of water—so that when it is some distance from its natural element, it is still provided with the necessary medium for respiration.

PLATE LXXII.

Gills of Anabas.

In passing from water-breathing to air-breathing animals, the transition is by no means sudden; for there exists an intermediate race, which are provided with both gills and lungs. The Siren (Plate LXXIII), the Proteus, the Axolotl of Mexico, the Menopoma, or "Hell-bender," of the Western rivers, are examples of this class of animals.—They are all provided with fringes on the side of the neck, which are

PLATE LXXIII.

Siren.

true gills; also with lungs, like those of air-breathing Vertebrates, but of a very simple character.—Frogs and water Newts, at one period of life, are water-breathing animals, but subsequently, become air-breathing. Such is the case in the Triton, the two stages of which are represented in Plates LXXIV and LXXV.

PLATE LXXIV. PLATE LXXV.

Triton with Gills.

Triton Adult.

Among the air-breathing animals the organs of respiration present themselves under two different forms. One, the form of air-tubes, which exist in many lower kinds, especially among Insects, and which circulate air through all parts of the body. It will be recollected that in speaking of the circulation of Insects, it was spoken of as being of an exceedingly imperfect kind; consisting of a pulsating vessel, which had the power of simply agitating the fluid, but not of distributing the blood through all parts of the body. And the reason why the circulating apparatus is not more complex is simply this, that it does not require a respiratory circulation; for in Insects, and in animals allied to them, the air is circulated through the body, instead of blood.

If you examine the abdomen of an Insect, you will find that it is made up of a series of joints, according to the articulated character of this group—on the upper side, series of plates, and another, on the abdominal side; and between these two series of plates, in every joint of the body, there is an opening, which is the respiratory orifice. When these respiratory openings are examined internally, they are found to communicate with tubes (Plate LXXVI) in which there are spiral threads, precisely like those met with in the air-tubes of many plants. These tubes extend through the muscular system, are found in the head, in the antennæ and the legs, even to the toes. Here, then, a special respiratory circulation of the blood is not required; for the air is carried through every part of the body.

PLATE LXXVI.

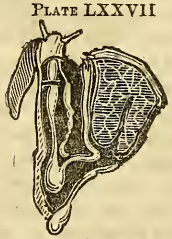
Respiratory Tube of an Insect.

The other forms of respiratory organs, such as are met with in the air-breathing Vertebrates, will be described, together with the Physiology of respiration, in the next Lecture.

LECTURE VIII.

At the close of the last lecture, I was speaking of the different forms which the organs of respiration assume in the different races of animals. It was stated, that the simplest condition necessary for the process, was a membrane with the animal tissues on the one side and the atmosphere on the other; the tissues, either in the form of cells, as in the simplest animals, or in the form of blood vessels, consisting of arteries and veins circulating blood in the immediate neighborhood of this surface, giving off the carbonic acid and the vapor of water and absorbing oxygen. In water-breathing animals this apparatus consists of fringes, as in Doris, (Plate LXVIII) Serpula, (Plate LXIX) and Glaucus, (Plate LXX) of Gills, as in the Crabs, (Plate LXXI) and in Fishes.

PLATE LXXVII



Lung of a Snail.

In passing to the air-breathing animals, you have the lung in its simplest condition, in the Snail, consisting of a respiratory sack, with a vessel branching on its walls, and the air in connection with it.

PL. LXXVIII.

Lung of Boa.

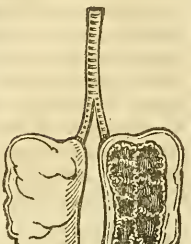
As you ascend still higher in the scale, all the modifications of the respiratory apparatus are more complex conditions of this primitive form. Amongst the Reptiles, the Frogs present us with the simplest structure. The lungs consist of two bags, on the walls of which are cells having but very slight depth, and on the walls of these cells, are distributed the vessels by which the process of respiration is carried on. (Plate LXXVIII.) In the Serpents there exists the same structure, the only difference being that the lung is very much elongated to accommodate it to their peculiar form. One of the lungs only is developed, the other remaining in a

PLATE LXXIX.

Lungs of a Lizard.

rudimentary state. The Lizard has a lung, the lobes of which are more nearly equal. In the Tortoise there exists another form of respiratory apparatus, where the organ becomes still more complex. Instead of consisting of a single cavity, the interior of the lung is divided into several cavities, all of which communicate with each other.

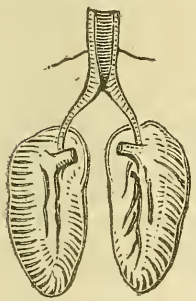
PLATE LXXX.



Lungs of Tortoise.

Ascending still higher, in the class of Birds the structure becomes still more complicated.

PLATE LXXXI.



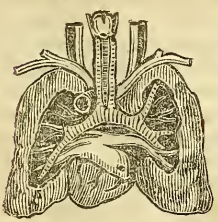
Lungs of a Bird.

Instead of consisting of large, open sacs, as they exist in the Reptiles, in the Bird the cells of the lungs do not exceed the size of a small fraction of an inch, less than half of a line in diameter.

There is this difference, however, between the Bird and the Reptile, as regards the structure of their lungs. In Birds the air not only passes into, but through the lungs, into large cavities, or air sacs, contained in the abdomen, and even into the bones. In Mammals all the conditions of respiration are rendered still more complete, by a continuation into all parts of the lungs, of air tubes for the carrying air backwards and forwards, as well as by the more minute subdivision of the air cells.

In Reptiles, the air passes to the surface of the lungs, through the trachea, into the first of the sacs, then from one to the other. In Birds the tubes are more generally distributed; but in Mammals the air tubes pass to every portion of the lungs.

PLATE LXXXII.



Human Lungs.

In this diagram of the human lungs, a portion of the lungs has been dissected so as to show the manner in which the blood vessels and air tubes are distributed.

However complex the lung of Mammals may appear, they are not essentially different from the lung of the lowest reptile. You have only to examine a single one of its cavities, to learn the

PLATE LXXXIII.

Blood Vessels of Air Cell.

structure of the whole. The elementary part of the lung is an air cell, with an artery which traverses its surface, and forms a series of capillary vessels which terminate in a vein, and by which the blood is carried back to the heart. The whole lung of the human body is nothing more than a repetition of these cells.

In studying the phenomena of which the respiratory apparatus is the seat in the living body, we may divide them into three groups: into those which are simply mechanical, for the transfer of air or the change of water, by which the process of respiration is effected; a second, including those which are chemical, and a third those which are physiological.

The mechanical processes, those which relate to the conveyance of air to the respiratory surfaces are effected in a great variety of ways.

In the simplest animals in which the respiratory organs exist, especially in the bivalve Mollusks, which are either lodged in the earth, or are attached to rocks, the change of water over their surfaces is effected by the vibratory cilia, which I have referred to as being also in some animals organs of locomotion. By keeping these cilia in motion, a current is kept up and the water constantly changed.

We can have evidence of this by placing a Muscle in a shallow vessel, with the edge near the surface of the water. Very soon, the shell will be seen to open a short distance, and the particles floating in the water will be alternately carried into and out of the shell, in obedience to the current formed by its vibratory cilia.

In others, they are produced by muscular contractions; and in none is this more obvious than in the Cuttle-Fish, which has an opening on the side of the fish where the water flows in, and is expelled through the siphon. Here we have the respiratory process not only subservient to the process of respiration, but also to locomotion; for it swims by means of drawing the water into its respiratory sac and forcing it out suddenly.

In Fishes, the means by which this is produced are quite different.

You have the arches, then the gill-covers, and the water entering the mouth, and as it is forced through the gills, passing over the respiratory surface, while the blood contained in the vessels is traversing beneath it.

In the Serpents and Lizards, air is introduced into the lungs simply by dilating the cavity of the chest, by the aid of the ribs. In the Birds, the sternum plays an important part, and is protruded forward; the ribs are straightened. To expel the air in the classes just mentioned, the lungs are compressed by the contraction of the walls of the

chest, and of the muscles of the abdomen. In Tortoises, however, where the ribs cannot serve for the process of respiration, because they are firmly united together, and in frogs, where no ribs exist, you have a substitute for them in the fold of skin under the chin, which may be worked up and down by the action of the hyoid bone and its muscles, so as to pump the air into the lungs as freely as may be required.

In the Mammals, where the process of respiration acquires the highest degree of perfection, as regards its mechanical movement, you have the muscle which is called the diaphragm, separating the cavity of the chest above from the cavity of the abdomen below; the ribs, likewise, assisting in the respiratory motions, as in the preceding animals.

The diaphragm is a thin muscle, arched upwards; in front, it is attached to the breast bone—behind, to the vertebral column—on the sides, to the walls of the chest. It changes its form in respiration, descending more nearly to a plane surface when it contracts, and thus increasing the cavity of the chest in a corresponding degree.

In speaking of the respiration of Birds, I refered to the peculiar structure of their lungs; to the fact that the lung was perforated for the transit of air through it. There is found to exist in the abdomen a series of sacs, which communicate with the lungs, and become filled with air during the process of respiration. But not only does the air pass among the various organs of the body, but in some Birds even into the whole skeleton. In this shoulder bone of the eagle, (which the Professor exhibited) you have a section of the upper part of it, where the shell of the bone is comparatively thin, showing the existence of a large cavity, which, during life was filled with air instead of fatty substance, as is the case in all animals excepting Birds.

In the Pelican, the air passes into the bones of the vertebral column, into the breast bone, into the bones of the arms, and down to the tips corresponding with the fingers. In the Condors and Vultures, it extends even into the large feathers on the wings, thus seeming to have a relation to their peculiar mode of locomotion. However, in order to state the whole truth in the matter, it must also be borne in mind that there are a number of birds, and those very rapid flyers, in whom the air does not enter the bones at all; and you have on the other hand the Ostrich, which never flies, into whose bones the air enters very generally. An interesting difference exists between the nocturnal birds of prey—the Owls, where the air never enters the thigh-bones; and the diurnal birds of prey, where it is constantly present.

Before proceeding to describe the chemical phenomena of respiration in animals, I wish to call attention to the relation which plants sustain with regard to the atmosphere, as contrasted with that sustained by animals. The tissues of plants, like those of animals, are made up of solid particles containing a large quantity of fluid. In common with all bodies which contain a quantity of fluid, greater than that of the medium by which they are surrounded, they lose a portion of it by evaporation, when exposed to the action of the atmosphere. There takes place, however, besides this, an exhalation of vapor, which is analogous in some respects, to the exhalation from the general surface of animals, and there exists in nearly all plants, a special apparatus by which this process is effected.

If you examine the under side of the leaf with the microscope, there will be found a series of orifices which are denominated "*stomata*," or mouths. They are formed by two cells touching at their ends, but leaving an open space between, and around these are other cells, which form a kind of frame-work. [The Professor chalked it out on the black-board.] Beneath that is a large cavity formed by the arrangement of cells [represented on the black-board] so as to form a chamber.—These *stomata*, or openings, have the power of contracting and expanding under the influence of light. In the day time they are open, in the night they are closed. There escapes a great quantity of exhalation during the day. Hales performed a series of experiments to determine the amount.—One single experiment is sufficient to give an idea of the amount of fluid exhaled. A Sun-flower, of three feet in height, exhales between twenty and thirty ounces in the twenty-four hours, only three of which were thrown off during the night time, showing that the presence of light exerted a very important influence.

Animals have a sensible and an insensible perspiration. The latter is being constantly poured out in the form of vapor. But if it passes out faster than it can be evaporated, it becomes sensible. Precisely the same thing takes place in plants. In them, when evaporation is slow, as in the morning, it accumulates and forms drops of fluid, which are ordinarily regarded as deposits of dew. But if a screen is placed over the plant so as to prevent the deposition of dew, these drops still make their appearance.

Not only does this exhalation of vapor take place, but there is likewise an exhalation of gaseous bodies into the atmosphere. If a plant be confined in a bell glass for a certain length of time, and exposed to the light, it will be found that the air is quite soon very materially changed, and if a candle be now introduced it will burn with greater brilliancy than in the open air. The moisture by which the plant is nourished contains carbonic acid in solution. The carbonic acid is decomposed in the leaves under the influence of light, and the oxygen is set free, a process just the reverse of that of which animals are the seat. But still, there is in the night time, and even in the day time, a certain quantity of carbonic acid exhaled by plants.

The explanation of this is, perhaps, as follows:

In the night, the carbonic acid reaching the leaves, does not become exposed to the action of light, no decomposition is effected and it is exhaled in the same condition as it entered the roots. In the day time, the small amount which makes its appearance is, perhaps, a portion which undergoes no change in consequence of the rapidity with which it permeates the tissues.

During the process of germination, however, carbonic acid is exhaled in considerable quantities, and generated in the tissues. The nutritive matter of the seed before germination exists in the form of starch, which, as such, is incapable of subserving nutrition. To become nutritive, it is converted into sugar, and this is attended with an evolution of carbonic acid. A similar evolution of this gas takes place during inflorescence, and, as in the Arum, is attended with a disengagement of heat.

In studying the chemical phenomena which take place in animals, during the process of respiration, it will be the most convenient to speak of them in two groups: those changes which take place in the respired air, and those which take place in the blood. I will first call your attention to the composition of the air itself. The atmosphere is made up principally of two ingredients. Nitrogen, of which it contains 79 parts in 100, and Oxygen, of which it contains 21 parts in 100; there is also a minute quantity of carbonic acid in the atmosphere—amounting only to 1-2000th part of every volume.

In passing the air through the lungs, among the changes which it undergoes, are the changes which relate to temperature, to moisture, and to the quantity of oxygen and carbonic acid. With regard to the change of temperature which takes place, it is only such as always takes place from passing into a warmer locality, if it be cold, or a colder one, if it be warm. Valentin found that if the temperature of the air was 50° when it was inhaled, it became 96° when exhaled, giving an increase of 46° degrees of temperature. If the inspired air was 107°, it lost 6°, being 101° when expired.

The presence of a cold atmosphere is alone sufficient to demonstrate an increase in the amount of moisture in the air exhaled from the lungs. How much moisture is exhaled from the lungs, is, however, very difficult to ascertain. If the breath be passed through a tube which is kept constantly cold, the moisture will be condensed in sufficient quantity to be measured. It has been ascertained by experiments conducted in a great variety of ways, that the amount of vapor which passes off from the lungs in 24 hours, in an adult, ranges from 16 to 27 ounces—subject, however, to great variations. For, it is found that the amount of moisture which escapes from the lungs will vary according to the season—according to the moisture of the air which we breathe, and according to the diet. Sometimes it happens that the lungs act in place of the skin. If the skin does not give off its usual amount of insensible perspiration, that is made up in part by the lungs and in part by the other excreting organs. From the lungs there also escape in addition to the vapor of water, accidental ingredients in the form of various volatile substances. Alcohol introduced into the stomach, is in part thrown off through the lungs; passing first into the general circulation, and from thence into the lungs, where it is partially exhaled.

One of the most important changes after the separation of the moisture, is the diminution of the oxygen in the air and the increase of carbonic acid. On examining the air after it has been breathed, it is found that it has the same proportion of nitrogen as it had previous to the process of respiration. Instead, however, of 21 parts of oxygen in the respired air, there are but 16 parts in 100. The air has lost 5 parts of its oxygen which has been absorbed. Instead of 1-2000th part of carbonic acid which it had previous to entering the lungs, it contains now 4 per cent.

The presence of carbonic acid may be shown merely by introducing into a vessel, air from the lungs, and then applying to it some of the usual tests. I will force into this tube air, just as it comes from the lungs. [The Professor blew, through a glass tube, air into an inverted receiver, filled with water]. One of the best tests for the presence of carbonic acid, is that of lime, which is perfectly transparent when in solution, but when combined with carbonic acid has a milky appearance. On agitating this with the expired air, the lime becomes visible in the form of an insoluble carbonate.

Another test to show the presence of carbonic acid, or the disappearance of oxygen, is the loss of power which the air has of supporting combustion. [The Professor introduced air from the lungs into a receiver, and then lowered a lighted candle into it, which nearly expired.] If the experiment be conducted with more care, the candle goes out the moment it passes below the surface of the vessel.

We have next to consider the changes which take place in the blood. As it passes through the blood vessels, on the surface of the air cells, the most obvious change is that of color. The blood in the veins being of a dark purple color, while that in the arteries is of a bright red. In its transit through the capillaries of the lungs, the changes which take place are two: the disappearance of carbonic acid, and the absorption of the oxygen. And to which of these is the change of color due? If it be to the separation of carbonic acid the color should become red when that alone is effected.—But it does not become so; we must seek another explanation. Magnus found, by exposing venous blood under an air pump, and removing the carbonic acid, the change of color was not effected, but on being exposed to oxygen or the atmosphere, the change was at once brought about.—So that the change is to be regarded as being

effected by the absorption of the oxygen, and not by the separation of the carbonic acid. The color of the blood depends entirely upon the color of the blood discs, so that whatever be the whole effect of the absorption of this gas, one of its effects is its combination with the discs floating in the blood. Here then there is one important fact gained, and will assist in the formation of a theory of the uses of the blood discs themselves.

In the transit of the blood through the lungs there is a slight change of temperature, but not so much as was imagined, when it was supposed that the lungs were the furnace by which the body was heated. It has been ascertained that the blood on entering the lungs, does not vary its temperature more than half a degree—an amount entirely inadequate to maintain its usual temperature.

On comparing the venous blood with the arterial, it is not to be supposed that the venous blood contains no oxygen, and that the arterial blood contains no carbonic acid. Magnus has shown most conclusively that both contain oxygen, and that both contain carbonic acid gas; but that arterial blood contains oxygen in excess, and that venous blood contains carbonic acid in excess.—Arterial blood contains ten per cent. of oxygen, and venous blood contains five per cent. Arterial blood contains 20 per cent. of carbonic acid; venous blood contains 25 per cent.

We have next to inquire into the source of carbonic acid. And this is an important inquiry. Lavoisier, Laplace, and those associated with them in their investigations into the nature of respiration, supposed that carbon was set free somewhere in the vascular system—was brought to the lungs—was thrown out into the air cells of the lungs—and that in respiration, it combined with the oxygen in the air cells, and there formed carbonic acid. But as the carbonic acid was afterwards found in the blood itself, this explanation would not hold good. It was then supposed that the oxygen of the air passed through the membrane to the blood vessels, and there combined with the carbon and formed carbonic acid, which was thrown off in respiration. But it was ascertained that the carbonic acid was found in the blood, at a distance from the lungs, and therefore that theory could not be correct. These observations were afterward combined with an observation made by Spallanzani, which was this: that Snails confined in an atmosphere of nitrogen, still continued to exhale carbonic acid; also, with those of Edwards on Frogs and Mammals, immersed in nitrogen, and found that the carbonic acid still continued to be thrown off. And the unavoidable inference was, that the carbonic acid was formed at a distance from the lungs.

Now the carbonic acid does not exist, except in a very small quantity, in the arterial blood. It does exist in a large quantity in the blood of the veins; it must therefore be introduced somewhere between the two, and that is in the capillary system. The formation of carbonic acid in this peripheral portion of the system—the parts most distant from the centre of circulation—enables us to form a theory with reference to its origin. The blood of the arteries, charged with oxygen, is carried to the distant parts of the body, the oxygen disappears, and is replaced by carbonic acid, this carbonic acid being the result of the combination of the oxygen of the blood with the carbon of the tissues, then passing into the venous system, it is brought to the lungs.

It also gives a more probable explanation than was formerly given of the generation of animal heat. If you can show that this formation of carbonic acid is constantly going on in the tissues of the body, you have the means of keeping up the temperature—each fibre generating its own heat, instead of having a central furnace in the lungs. That the formation of carbonic acid is in part at least the cause of animal heat, is obvious from the fact that both keep pace with each other. During exercise and during the day, the temperature of the body is higher than when at rest, or during sleep. Carbonic acid is more freely evolved in a state of activity than during repose, and in the day, than during the night. With regard to the separation of the carbonic acid from the blood in the vessels of the lungs, and its discharge into the atmosphere, the explanation of this has been a subject of great interest, and it would seem that it is to be explained rather on the score of a physical property of gaseous bodies, than on any strictly speaking vital action of the body.

And in order to appreciate this, I would call to your mind the facts referred to in the explanation of the absorption of fluids; that when two fluids of different densities are so placed that the heaviest is at the bottom, they become gradually mixed; and this will take place even when an animal membrane is interposed. Gases follow a similar law. If you have a vessel containing one gas, which is heavy, at the bottom, and another containing a lighter gas is placed above it, and the two communicate by means of a tube, a mixture will take place. If the one below is filled with carbonic acid, and that above with hydrogen, carbonic acid being one of the heaviest of the gases, and hydrogen being the lightest, they will mix together, and an interchange will take place, even if these are connected only by a capillary tube. If there be an animal membrane instead of the tube, the same result will follow. This tendency of gases to intermix is very general, and takes place, agreeably to a law known as the "law of the diffusion of gases."

What have you in the lungs? You have the oxygen of the atmosphere on one side, and the carbonic acid on the other side, and a membrane, consisting of the walls of the cells, between the two. The carbonic acid passes readily towards the air on the outside, and the oxygen in like manner, passes through the membrane into the blood

within. That this is a physical process rather than a vital one, is shown by the simple fact, that respiration, or the action of the air on blood, may be effected out of the body by introducing venous blood and exposing it to pure oxygen or the atmosphere. The oxygen will pass through to the blood within, and the carbonic acid will pass out. The blood will become red, and undergo precisely the same changes as it would have done in the living body. Another fact, and a very important one, which tends to show that this interchange may be agreeable to the law of the diffusion of gases, is the fact that, after the air which you breathe becomes charged with an excess of carbonic acid it no longer arterializes the blood. Accordingly, the nearer the atmosphere around us is like the air exhaled from the lungs, the less rapidly does the oxygenation of the blood go on. In other words, when the air on one side of the animal membrane and the blood on the other become equally charged with carbonic acid, that difference in density no longer exists which is necessary for their mutual displacement. In the case of fluids, if syrup or a fluid of the same density be on both sides of the membrane, no interchange takes place —and the same is true of gases.

Allen and Pepys ascertained that when the atmosphere becomes charged with ten per cent. of carbonic acid, the elimination of this gas by the lungs was no longer effected. And this is important, as bearing upon the necessity of maintaining the respiratory medium in a proper state of purity. A human being placed in an atmosphere of 10 per cent. of carbonic acid, would survive but a short time. If the carbonic acid is even in less proportion than this, an effect is produced the more injurious as it approaches to this percentage of the acid.

You have instances in great abundance of the destruction of the life of persons exposed to an atmosphere containing a larger proportion of carbonic acid than is consistent with the healthy performance of the function of respiration.

No instance is more remarkable than the case of the prisoners confined in the Calcutta prison, commonly known as the "Black Hole," where 146 persons, most of them British soldiers, were imprisoned, in an apartment 18 feet square. The only entrance for fresh air was through two small windows; and both of these being on the same side of the room, in the course of a few moments they became very much affected by the deterioration of the atmosphere—soon great difficulty of breathing came on, then delirium, next stupor, and finally, of 146 persons imprisoned, the next morning 123 lay dead on the floor.

Although the carbonic acid may not in all cases be evolved in sufficient quantities to be appreciable, yet it must prevent more or less the due performance of the respiratory functions. In Paris the amount liberated in rooms has been investigated with a great deal of accuracy. There, the air has been taken from the wards of hospitals, from lecture rooms, and from the theatres. In England, when Dr. Dalton made an analysis of the air where 500 persons had been sitting for two hours, and fifty candles had been burnt, he found that it contained as much as one per cent. of carbonic acid.

Le Blanc, in examining the air of one of the wards of a Paris hospital, where the doors and windows had been closed during the night, found that the carbonic acid had increased to five times, the usual amount; and in the lecture room of the Sorbonne, where a class had been confined but a single hour, the carbonic acid had increased to three times the amount naturally existing in the atmosphere.

The respiration of Fishes and aquatic animals is in no way different from those living in the air, except as to the medium of respiration. The atmosphere is dissolved in the water, and the whole process of respiration in water-breathing animals is performed by causing the fluid to pass over the surface of the gills, when the oxygen is removed from it, and carbonic acid is set free.

In examining the structure of animals which have an aerial respiration, and yet live in the water, there are often times very remarkable adaptations to enable them to remain beneath the surface.—Animals which remain under water a great length of time, as the Otters among Amphibious Mammals, and the Ducks among Birds, have a receptacle in which the venous blood is accumulated, and is only allowed to pass through lungs on coming to the surface. In the Whales, however, there is not a chamber for the accumulation of venous blood, but in the walls of the chest there is a receptacle in the form of a plexus of arteries, for the accumulation of arterial blood, which they may use up as it is required. Many Reptiles have a still different arrangement. Tortoises, for instance, always take down with them a large quantity of air in their sac-like lungs, which is more than is necessary for their immediate demand, so that they are still breathing, although below the surface.

This concludes what I have to say with regard to the processes concerned in the purification of the blood. The subject of the next lecture will be the Nervous System.

LECTURE IX.

In attempting a classification of the functions of the body, at the commencement of the course, I divided them into two primary groups; into those of Animal Life, and those of Organic Life. Those of animal life were further subdivided into the Motory system, and into the Nervous system.—The functions of organic life, into those of Nutrition and Reproduction.

I have considered the functions of the motory, and of the nutritive system; and we have remaining those which preside over the most important processes of the body, located in the nervous system, which is the seat of the will and intelligence, and forms the means of communication between the intelligence and the external world.

The nervous system is not known to be universal in the animal kingdom. Wherever it is known, it is positively certain that the being in whom it is found is an animal. But there are some animals in whom no trace of a nervous system has hitherto been detected. The Hydra is in this condition. The most accurate observations of Microscopists have not detected a trace of nervous fibres. The Actiniæ, which are very closely allied to it, present us a nervous system, similar to that of the Radiated class.

It is not improbable that a nervous system may be detected in the Hydra, though it would seem that it ought to have been detected before this. Physiologists who have been unwilling to give up the idea that one does exist, have supposed that a nervous system, in a "diffused form," was present in such animals as the Hydra. To illustrate what is meant by a diffused nervous system, I will recall to you what I have said in a former part of this course. It will be recollected that respiration is a process which is carried on in the Hydra, as well as in the higher animals. But in the Hydra it is carried on by the general surface of the body. There is no especial organ appropriated to this function. But as you ascend in the series, you will find that there are certain portions set apart for respiration; among them, you have in the Doris, the fringes on the back, in fishes, the gills, and in the higher animals, the lungs.

The same may be said of motion. A distinct muscular system does not exist in the Hydra, all its parts being endowed with contractility. But as you ascend in the animal series, there are muscles devoted especially to this function.

Now, it is supposed that, in these simple animals, a nervous system may be diffused through the whole body; that each portion of the body, and each part of the surface may be endowed with its own power of receiving sensory impressions. This view is not improbable, and although it must be regarded in the light of an hypothesis, yet there is nothing unreasonable in it. Especially when you compare it with what is absolutely known with regard to the diffused condition of other functions in these lower animals.

As we have not, then, a nervous system which we can detect in the Hydra, we must take our departure from another point, and examine first those animals which present it in the greatest degree of simplicity. And there is none in which it is more simple than that which is presented in the Star Fish. If a Star-Fish (Plate LXXXIV) be examined, there is found existing around the central cavity, which is the stomach, a chain, or a series of bodies, one of which corresponds with the base of each of the rays, which, in this species, are five. And if the rays are more numerous than represented in this figure, they are generally multiples of five, and there is found one of these bodies at the base of each additional ray.

PLATE LXXXIV.

Star-Fish.

These bodies are denominated nervous centres, or *ganglia*, and from each of them proceed fibres

to the distant parts of their respective rays. If the nervous system be examined still further, it will be found that other fibres extend from the ganglion at the base of one ray, and connect it with the ganglia at the base of the adjoining rays, and by this means all the ganglia are connected together.

These three ingredients—the central body, or ganglion, the nerves going from it to the distant parts of the rays, and those fibres going from one ganglion to another, connecting them together—constitute the elementary nervous system—elements which are repeated throughout the whole animal series.

Each nerve consists of a series of fibres which pass from the skin towards the central parts, and another set of fibres which go from the centre towards the muscles. The first transmit an impression from the surface towards the centre, producing sensations; whereas in the other instance they transmit an influence from the centre towards the muscular fibres, causing them to contract. So that you have here the means which transmit the exciting cause of sensation and motion, or the nervous system, giving rise to sensation through one set of fibres, and motion through another.

The third element is a series of fibres passing from one ganglion to another, constituting what are called commissures; being, however, nothing more than fibres, which, instead of passing from the skin, or to the muscles, pass from one ganglion to the other, uniting them into one series, instead of leaving them single and insulated masses.

Before proceeding further, it will be desirable to ascertain what are the minute anatomical characters of these elements of a nervous system—of the fibres which conduct influences, as well as of those other parts which are denominated nervous centres.

If the fibres, which pass from a ganglion towards the general system, be examined under the microscope, they will be found to have the structure represented in this figure.—Take a nerve and tear it into minute fibres, place one of these under the microscope, you will find that it is still composed of fibres more minute, the smallest being not more than 1-1500 of an inch in diameter.

PLATE LXXXV.

Nervous Fibre.

These are found to be tubular, consisting of a membranous sheath, which contains a substance that is perfectly transparent at first, but on being exposed to the air or water, becomes somewhat opaque; there appear within it minute globules. (Plate LXXXV.) The contents of the sheath consist of a substance which is semi-fluid, having a pasty or pulpy character, as may be shown by pressing the nerve-tube between two plates of glass, when the contained matter will protrude at the end. When examined in the living body, there has never been detected anything like motion within the nerve.

In examining the fibres which go from the Nervous centres to the eye, or the ear, or the organs of the special senses, it was thought by Ehrenberg that a different kind of nerve existed, for it appeared as in Plate LXXXV [right half]. But this was found to be purely accidental, not existing naturally, but the result of the manipulation to which it was subjected.

In tracing the nervous fibres to their termination, either to the muscles or to the brain, it will be seen that they do not terminate by free extremities, but in loops, as shown where they are taken from a cavity of the tooth; and the same is generally true if they be traced into the brain or ganglia, from which they are derived.

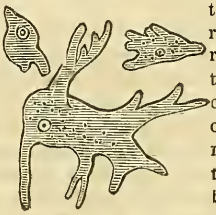
These ultimate nerve-fibres are bound together in a common sheath, and thus form a nerve. If they be traced along the course of a nerve, there has no instance been found in which they are branched. Every fibre is kept entirely distinct from every other fibre. Fibres may pass from one trunk to another, but they do not form any direct communication with one of its filaments. A nerve, then, consists of independent tubes passing from the nervous centres either to a muscle or to a free surface.

PLATE LXXXVI.

Ganglion Cells.

The central bodies, or ganglia, from whence these fibres proceed, are made up of minute bodies, called nerve cells. Some of these are represented in Plate LXXXVI. Some are round, others oval; but all of them presenting in the interior the nucleus characteristic of the nucleated cell. Oftentimes, projections extend from the surface of this cell, as represented in Plate LXXXVII, in some cases to very great length; as represented in these several figures. They are said to be in some instances continuous with nerves, or with the origin of the nerves. In a few instances they have been traced to be continuous with them.

PLATE LXXXVII.



Ganglion Cells.

The figures here given are from the human brain, but similar ones exist in the nervous centre of the lower animals. The ganglion is in all cases made up of this ingredient, in the form of a nucleated cell.

With regard to the fibres which pass from one ganglion to the other, they are of the same structure as represented in Plate LXXXV.

In speaking of the chemical composition of the

different tissues, I referred, in a former lecture, to the fact, that the active tissues of the body contained albumen in large quantities; whereas the others, the passive organs, as bones, ligaments, &c., were made up mainly of gelatine. It has been observed, that there is a difference in the amount of this element, which is in proportion to the energy and activity of these organs. The nervous system of an infant, on analysis, is found to contain a smaller per centage of albumen than that of an adult; and it is still further stated, that in an idiot it was found to correspond in its proportion with that of an infant. In adults and in young persons, the amount of albumen is at its maximum.

Anatomically, the elements then of the nervous system consist of centres, in the form of ganglia, and of conductors, in the form of nerves. We have now to consider them in action, or to consider them physiologically.

Under the influence of the will, an influence originated in the nervous system is transmitted to different parts of the body and calls the muscles into action. In consequence of an impression made upon the general surface, an influence is transmitted towards the central portions of the nervous system, and is followed by something more than mere irritation, like that which takes place in the sensitive plant. It is followed by sensation and perception. The nature of these, we have already shown in the Hydra. The same is true of the Actinia, which is similar to the Hydra, and is now selected for illustration, because a nervous system is known to exist in it. If you cause a grain of sand to touch one of its tentacles, they retract, and it is rejected as useless; but if an animalcule which can be used as food come in contact with the tentacles, instead of being rejected, it is seized by the tentacles, passed from one to the other, and at last taken into the mouth. Here the animal distinguishes between the grain of sand which is useless and the animalcule which can serve for its nutrition, or, in other words, it *perceives* a difference among the *impressions* made upon it by surrounding objects.

As the ganglia are the seats to which influences are propagated, and from which motory power is transmitted, it supposes the necessity of an influence passing backwards and forwards. The nerve is merely a conductor. If the nerves of the higher animals are tied, then the influence between the distant portion and the nervous centre is entirely cut off, and the part to which it was distributed paralyzed. This would seem to involve the existence of an influence of some kind which is transmitted. And the first question which arises is, as to the nature of nervous influence? It is not to be expected that any answer will be given as to its *essential* nature. The precise nature of it is not known, and probably never will be known, any more than is the nature of gravitation. This last is known only by its phenomena. The question is not asked with regard to the essential nature of nervous force, but whether it be identical with any known force, or whether it have any phenomena which will enable us to regard it as an independent force. The nervous influence, whatever it be, has, in the rapidity with which it is transmitted, and in the manner in which it is conducted by fibres, led Physiologists to suppose that it is identical with, or in some respects strongly resembling, electricity.

From the days of Galvani to the present time, since he succeeded in causing motion in the muscles by electricity, there has been thought to be some connection between nervous energy and electricity. He excited muscular contractions in a frog, by passing a current through a nerve. These muscular contractions have been excited in higher animals, and even in criminals recently executed, all the muscles being incited by transmission of the electrical influence through the nervous system.

But it is not to be inferred, because electricity may produce these effects, that it is identical with nervous force. For there are other kinds of influence which will produce the same effect. If the nerve be pinched, or if a pin prick it, the same result takes place in a modified form. Or if a chemical irritant be applied, a similar effect will follow. In order to prove that electricity and nervous force are precisely alike, we must find that they both respond alike to the same tests. How do we know electricity? We know it from its being able to decompose certain substances in solution when its current is passed through them.—Electricity has the power of giving a shock to the muscular system when passed through the nerves. It will produce in other circumstances a spark; and when passed around a piece of steel it renders it magnetic. But the most delicate of all tests of electricity, is the power which it has of causing a needle already magnetic to change its direction, or of "deflecting" it. If an electrical current be passed over a needle, it will be changed from its natural direction to one approaching more or less to a right angle with the current passing near it.

Now, not a single one of these phenomena has been made manifest by nervous force. Matteucci found in the leg of a horse, that when the nervous force passed along one of the great nerves, it had not the slightest effect upon the most delicate galvanoscope; the needle not being in the least deflected. There is another objection to their identity. The nerves do not form equally good conductors of the two forces. It is found that a nerve is a very poor conductor of electricity, inferior to muscular fibre; so that it is impossible to circulate the electric fluid through the nerves to the distant parts of the body, because of the muscular fibre being a better conductor than the nerves themselves; and the nervous influence, therefore, were it identical with electricity, would return to the nervous centres, through the muscles, before it could reach the distant parts of the body.

Another objection to the identity of electricity and nervous force is, that simple compression of a nerve will prevent the transmission of the second, but not of the first. Any one applying compression to a nerve interrupts the communication between the nervous centres and the muscles. But electricity travels through the nerve just as well with compression as without it. These objections, then, would seem to render the inference altogether an unfair one, which would identify these two forces. It does not prove that they are not identical; it only proves that their identity has not yet been detected.

It is not long, since the three forms of electricity —common electricity, galvanism and magnetism, now regarded as one and the same—were supposed to be wholly distinct. And it is not improbable that nervous force may yet be discovered to be still another condition of electricity.

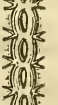
The simplest condition known of the nervous system is that of the Star-fish, already referred to, where the nerves radiate from a series of ganglia arranged horizontally around a common centre; and this is the characteristic form of the nervous system of the whole class of Radiata.

The Articulata, in their essential characters, it will be remembered, are made up of a series of rings, each successive ring being a repetition of that which preceded it, as is the case in the Centiped, (Plate VII). In the higher Articulata these rings are modified with reference to the different kinds of locomotion, of which there is an illustration in Plate VIII. The nervous system in this division of the animal kingdom is equally characteristic, and is composed of ganglia arranged in a longitudinal series, which, with their connecting fibres, form a chain extending the length of the body. If all the rings are of nearly equal dimensions, as in the Talitrus and Julus, then the nervous system will consist of a chain of ganglia, of equal

PLATE LXXXVIII.

Julus.

PLATE LXXXIX.



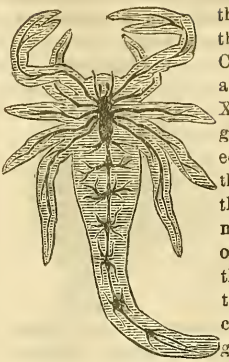
Nervous System of Talitrus.

size, as in Talitrus, (Plate LXXXIX). Each joint has its ganglion, and that is united with the ganglion below and above, and from these are given off the nerves

PLATE XC.

N. S. of Lobster.

PLATE XCI.



N. S. of Scorpion.

which are distributed to the different segments of the body. In the higher Crustacea, the Lobster and the Scorpion, (Plates XC and XCI) the ganglia are no longer of equal size. If you recall the different segments of the Lobster, you will remember that in one part of the body, the thorax, the rings are much larger than in other parts, as it carries not only the organs of locomotion, but also those of respiration.

PLATE XCII.

Crab.

In another form of Crustacea, Crabs, the nervous system of one which is represented in Plate XCII, all the rings of the central part of the body are fused together, and those of the tail being imperfectly developed, a corresponding concentration seems to have taken place in the nervous centres. They are united so as to form two parts, one for the head and one for the rounded centralized body. In Insects and Worms, a class which is constructed on the same general plan, the ganglionic system has the same general form as seen in that of the Leech, (Plate XCIII).

PLATE XCIII.

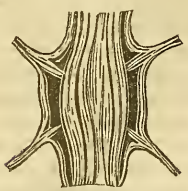
Leech.

It may be said with regard to all the Invertebrate animals, whether Radiates, Mollusks, or Articulates, that the nervous system forms a ring at one portion, through which passes the œsophagus or the alimentary canal. In the Radiata, the ganglia are arranged symmetrically around the œsophagus; but in the two other divisions it is only the anterior portion which forms such a ring, as seen in the Lobster and the Slug. If the ganglia about the head be examined with reference to the functions, it will be found that those above the œsophagus always correspond with the organs of sense, there being always one for the antennæ; and if there be eyes, then you have an optic ganglion for presiding over the sense of vision. But if the eyes do not exist, then this ganglion is not present.

If one of the ganglia of the nervous cord be examined with reference to its minute structure, it is found to be made up of the following parts (Plate XCIV and XCV.) The nerves will be found some of them to pass in towards the centre of the ganglion, and others passing into it ascend and terminate in the ganglion at the head. The series

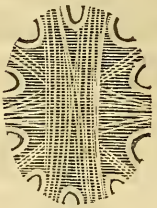
passing towards the central portion of the ganglion become intermixed with vesicles which are lodged there, and are true ganglion cells.

PLATE XCIV.



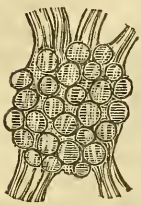
Ganglion of Centiped.

PLATE XCV.



Ganglion.

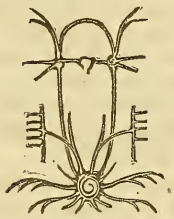
PLATE XCVI.



Ganglia.

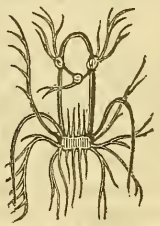
In the Articulated animals, as in the instances which have just been given, in the Crustacea, in the Worms, and in the Leech, you have all the ganglia arranged, one behind another. In Mollusks, the arrangement of the ganglia is quite different, as will be seen by comparing the nervous systems in Plates XCVII. XCVIII, & XCIX, with those of the Articulata, described above. The former in no instance forming a chain of ganglia as in the Articulata, but consisting of an œsophageal ring, with other ganglia attached, but in an unsymmetrical manner.

PLATE XCVII.



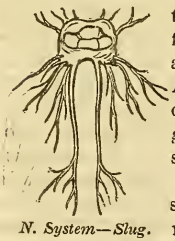
Nervous System of Scollop.

PLATE XCVIII.



Nervous System of Oyster.

PLATE XCIX.



N. System—Slug.

In considering the nervous systems of Invertebrate Animals physiologically, the functions which have been referred to are found to exist in all; that is, they are capable of being influenced by external impressions in such a manner as to give rise to sensations and perceptions; and are capable of emitting an influence which gives rise to muscular contractions. In the Star-Fishes it is probable, from the similarity of the ganglia as to their size, the nerves which are connected with them, and the parts with which they are in relation, that they are also endowed with similar properties. In the Articulata and the Mollusca, the two ganglia at the head, and which form the upper portion of the œsophageal ring, are the ones from which the nerves are derived that are distributed to the tactile organs, to the eyes, or the tentacles to which the eyes are attached, and to the supposed organ of hearing. They may, therefore, be regarded as the seats of special sensibility, and analogous to the brain of Vertebrata. With regard to the ganglia situated below the intestinal canal, (for this is the position of all that portion of the chain which follows the œsophageal ring,) it is quite certain that they are capable of receiving impressions and emanating an influence which will give rise to muscular contractions, and this independently of those ganglia which are connected with the organs of sense.

Mr. Newport has proved, and this accords with the results noticed by numerous observers, that if a Centiped be divided by cutting through the body, a short distance behind the head, so that a few legs shall remain in connection with the anterior segment, this last will move about in such a manner as to give unequivocal evidence of volition; it will avoid objects, go over them, turn to the right or the left with great facility; whereas the other segment will move straight forward till it meets with some obstacle, then moves no farther, turning neither to the right or the left. To prove that the influence of the motions of the posterior segment are to be attributed to the influence of its ganglia, it has been shown that if one or more of the ganglia be destroyed, the motions of the segments of the body will be destroyed to a corresponding degree.

From the facts above stated with regard to the Centiped, it would appear that the will is certainly in action when the anterior part of the body moves, but there does not exist equal evidence with regard to the motions of the posterior portion, and in fact voluntary motion in the latter is wholly denied.—It will be found very difficult, however, to prove that the ganglia corresponding with the organs of sense are the only seats of volition. A Fly that has had his head torn or cut off, will stand upright on his feet, will go through all the movements of cleansing his wings with his hind feet, and even cleanse the feet themselves, of the dirt removed from the wings, by rubbing one foot against the other. Such an act, having all the appearances of object, design, it will be very difficult to show is not voluntary. If it be voluntary, it is certainly independent of the anterior, or so called cerebral ganglia.

Passing from the Invertebrated to the Vertebrated series, we have the type of the nervous system wholly changed, presenting itself in an entirely different anatomical relation to the rest of the animal organism. The Vertebrated division of animals is characterized by the existence of a vertebral column, to which are attached the various parts which form the skeleton. The animals which compose this series, were not called Vertebrated animals simply from having a vertebral column, but because this was an index of something else, far more important—the vertebral column forming a canal for the protection of a particular form

of the nervous system, consisting of a brain and spinal marrow.

In the Invertebrated animals, the nervous system has no separate cavity for its protection; instead of being in a canal by itself, it is lodged in the same cavity with the other viscera.

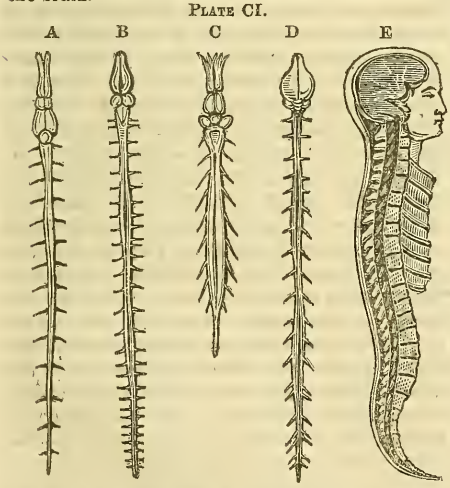
There exists in all the Vertebrated animals a central axis or cylinder, from which are given off the various pairs of nerves to the right and left, a single pair corresponding to each piece of the vertebral column. In the Amphioxus, the simplest Vertebrated animal hitherto discovered,

PLATE C.

Amphioxus.

(Plate C) the central cylinder, with the nerves given off in pairs, constitutes the whole nervous system. But in the fishes generally, there is developed at the anterior part of the cylinder, a series of ganglia, which are connected with the organs of sense, and taken collectively, constitute the brain.

PLATE CI.



Spinal Chords and Brains of Vertebrata—A *Perch*, B *Tortoise*, C *Frog*, D *Pigeon*, and E *Man*.

The spinal marrow may be regarded as the fundamental portion of the nervous system of the Vertebrata, as this is the only portion which is never absent, and ought therefore to be presented first for consideration.

Examined anatomically, the spinal chord is found to be made up of two elements, as shown in a transverse section in Plate CII—an external white,

PLATE CII.

Section of Spinal Marrow.

fibrous, or tubular portion, and an internal colored "vesicular," or "cellular" portion; the former having precisely the structure of ultimate nerve-fibre, and the latter of the element of which the ganglia and the brain are composed. The nerves are not connected with the spinal marrow by simple attachment, but are divided into numerous roots, and the roots arranged in two groups, as shown in Plate CIII. viz., an

PLATE CIII.

Roots of Spinal Nerves.

anterior and a posterior group. Each of these unite and form a separate bundle, and subsequently the two bundles unite and form a single nerve. On the posterior bundle there is always present, just before it unites with the anterior, a rounded body, which has the structure of the ganglia of the Invertebrata. Before determining the nature of the functions of the spinal cord itself, it will be desirable to ascertain the properties of the classes of fibres constituting the roots of the spinal nerves, as the latter will serve, in some measure, as a key to the former.

An English Physiologist, Alexander Walker, in speculating upon the uses of the roots, but unsupported by observation or experiment, ventured to assign a use for these different fibres; and as is almost invariably the case under such circumstances, although he had but to guess between two things, he guessed wrong. He asserted that the anterior roots were in relation to sensation, and the posterior to motion.

In the lower animals there is physiological evidence of two kinds of properties in the nerve, that the nerves are subservient to sensation, as well as to motion, though it cannot be proved that the fibre which transmits volitional influences is different from that which transmits sensitive impressions. But in the Vertebrated series, we have the means of demonstrating that two kinds of fibre exist—that there is one kind subservient to motion, and another kind to sensation.

In examining the nerves which are attached to the spinal marrow, it was a matter of observation centuries ago, that each nerve was provided with two kinds of roots at its attachment with the spinal cord, but no one suspected a difference of function. More recently, Boerhaave, however, recognized the fact that, when examined *physiologically*, there existed nerves of motion and of sensation; and when examined *anatomically*, that there existed two kinds of fibres, (derived from the anterior and posterior roots,) and which, although enclosed in the same nervous trunk, yet the individual fibres always remained distinct; but in speculating upon the uses of these fibres he asks, "Who shall say that this moves or that that feels?"

Subsequently, Sir Charles Bell determined to ascertain their true nature, from experiment and observation. He found that if the spinal cord be exposed, and any irritation, as the point of a probe or a needle, be applied to the anterior roots, immediately there follows violent muscular contraction;

and this was so constantly the case, that he regarded these filaments as the true conductors of the *motory* influence. If a similar irritation were applied to the posterior roots, no contraction followed.—As Sir Charles Bell, from motives of humanity, experimented, in all except the first instance, on animals rendered insensible by a blow on the head, he obtained no positive evidence with regard to the functions of the posterior roots; but collecting together facts derived from diseased conditions of the human body, together with the negative fact that the posterior roots were not motory, he inferred that the posterior roots were composed of *sensitive* fibres. More recent experimenters, especially Magendie and Longet, in France, and Muller in Germany, have placed his conclusions beyond the reach of doubt

Each spinal nerve, therefore, may be regarded as consisting of two sets of fibres: an *anterior* or *motory* series; and a *posterior* or *sensitive* series. The posterior are provided with a ganglion, and the anterior are destitute of it.

LECTURE X.

The simplest form of the nervous system which is known to exist in the animal series, is that which has been described as existing in the Star-Fish, consisting of a number of ganglia, with nerves passing to the rays, and filaments passing from one ganglion to the other.

In the Invertebrated animals generally, there is a ring formed by the nervous system around the intestinal canal: in the Star-Fish, in a horizontal plane; and in the Articulata, a ring in an oblique plane: the same is also true of the Mollusks.

There is a distinction between different portions of the nervous system, drawn from their physiological characters. Thus in the Mollusks and Articulates, there always exists a series of nervous fibres, which pass from the first pair of ganglia to the organs of sense—some to the eyes, others to the *antennæ*. Physiologically considered, there are two ganglia, corresponding with the head, and are considered as the seat of volition. In experiments, the parts behind are removed from the influence of the will, by dividing the chain with a knife. The posterior ganglia, however, are the seat of certain kinds of influences, which are independent of the anterior parts. For, if an insect has its head cut off, if the legs are irritated, there is still a certain amount of motion, showing that the movement can take place, independent of the so called brain.

In the Vertebrated animals, the nervous system is differently arranged from what it is in the Invertebrated series, where it is without a vertebral column. In the Vertebrata, there is an axis extending nearly the whole length of the vertebral canal, and giving off the nerves to the right and left, just as the chain of ganglia give off their nerves in the Articulated animals. The simplest form is that of the Amphioxus, the simplest known member of the Vertebrated series, where the nervous centres are made up of a cylinder extending the whole length of the body, giving off nerves at each side, but not enlarged, at the front part, into anything like the brain. In all the higher forms, there is developed on this cylinder a series of bodies, of nearly equal size in fishes, which are considered as the fundamental parts of the brain; for they exist in all the higher forms. This central axis of the nervous system in the Vertebrated animal, comprising the brain and spinal marrow, has received the particular designation of Cerebro-Spinal Axis. Formerly the brain was considered as a part, or something entirely distinct from the spinal marrow; but as you pass along the Vertebrated series, you find that the brain is developed from the spinal marrow. The spinal marrow was shown to be made up of two ingredients, as is the nervous chord in the Invertebrated animals. The nerves are connected with the spinal chord by two kinds of roots—an anterior series, or motory, and posterior, or sensitive roots; the last are distinguished from the former by the existence of ganglia. These two kinds united, form the trunk of a spinal nerve, the posterior branches transmitting those impressions which are followed by sensations and perceptions; and the others transmit those influences which are followed by muscular motions.

It now remains to speak of the functions of the spinal chord itself. In considering it Physiologically, since there exist two substances, one fibrous and the other vesicular, if the proposition laid down in the last lecture be correct, that one is the dynamic portion, and the other a conducting portion, then the spinal marrow ought to be a conductor and a centre. That it is a conductor, there can be no sort of doubt. The most abundant evi-

dence, derived from experiments and the results from various accidents, demonstrate this. If an animal be injured by the fracture of the vertebral column, so that the spinal marrow is compressed, then follows paralysis of all the parts below. A person who has had the spinal marrow compressed, is incapable of moving any of his muscles below the seat of injury; and any impression which is made upon the skin is not transmitted to the brain, so that there can be no sensation or perception. That this merely acts as a conductor, is shown by the effects of injuries in different parts of the column. If the vertebræ be fractured at the lower portion of the vertebral column, then only the lower limbs are paralysed: if in the middle of the back, the lower part of the body, with the lower limbs; and as you ascend, the higher the injury, the more complex is the paralysis. And if it be, as sometimes happens, quite high up, the feet, the arms, and the body are all paralysed. Such a person, placed in bed, with the clothes thrown over his body, has no consciousness of any part except the head. Any injury inflicted upon the arms or legs, will not be followed by pain, and will not give him any perception of the existence of the distant parts of the body: as far as his own consciousness goes, he is only a living head. The roots of the nerves are attached, it will be remembered, to the spinal marrow at definite points throughout its whole length; one series of roots, the motory, being attached on a line about one third of its circumference from its centre, in front, and the others at a corresponding distance from the centre, behind.

The question arises, whether the parts of the spinal marrow, to which the different roots of the nerves are attached, also have different functions—whether the spinal marrow is provided with fibres on the front side, which transmit motory influences, and on the back side with other fibres, which transmit sensory impressions.

Sir Charles Bell was led to infer that the spinal cord could be divided into different tracts. He inferred that the tract of the spinal marrow which corresponded with the origin of those nerves, was sensory, conducting the sensory impressions; and the other part was simply motory, and corresponded to those conveying motory influences.

Anatomical evidence exists in support of that view. For, if the nerves are traced into the spinal cord, in tracing the nervous fibre into its substance, it is found that they pass in and then ascend towards the brain: the nerves passing up are supposed to be continuous with the nervous fibres, which go to make up the brain itself. So that you have the anatomical evidence, as far as it goes, in favor of this view. The evidence of experiment also goes in support of it. For when the spinal chord is divided into two portions, by cutting it through with a knife, if a stimulus be applied to the front part, or motory portion of the upper segment, it is found that no result follows: if it be applied, however, to the corresponding part of the lower segment, it will be followed by contractions of all the parts below, so that this tract transmits an influence which causes muscular contractions. On the sensitive side, if a stimulant be applied to the chord on the upper segment, pain immediately follows. But if it be applied at the same side of the lower segment, there is no result. If a stimulant be applied to the posterior part of the spinal chord after it has been divided, there is a sense of pain experienced; but if it be applied to the anterior part, muscular contractions are excited. These facts assist in proving that one part of the spinal chord is a conductor of motory impressions, and the other part of sensory impressions.

Evidence of various kinds exists in support of this conclusion. And if it be desirable to cite instances, they exist in considerable numbers in the records of surgery. I will refer to one only, inasmuch as it answers as much the purpose of an experiment as if it had been made expressly for the purpose.

The case was that of a man, an officer of the Municipal Guard of Paris, who, during the time of the revolution in 1830, received a blow from a knife on the back of the neck. He fell to the ground, paralysed on one side, the paralysis being of motion, but not of sensibility. The knife was broken, and the point was left in the wound. The man was carried to one of the military Hospitals, and all the symptoms were carefully noticed. His sensibility on both sides of the body remained entire till within a day or two of his death, which occurred about four weeks after the accident. It was found that the knife passed obliquely through the spinal chord, cutting off that portion which is in relation with the motor roots, but leaving the sensory roots untouched. Here, then, was as exact an experiment as could be desired: dividing one part and leaving the other untouched, and obtaining a result in accordance with the views derived from actual experiments of Physiologists.

This interesting case, in connection with the other evidence, only places this view in the light of a highly probable theory. For there are some exceptional cases, which are derived from disease, in which the opinion is not so well supported. Instances are on record, in which the spinal chord was very much diseased, without the results following, which the preceding statements might lead us to expect. At the same time, the evidence from experiment is uniformly on one side. The exceptional cases are from diseased conditions, and these every Physiologist knows are the most difficult to reduce to any rule. The spinal chord, then, may be certainly regarded as a conductor of motory and sensory influences, between the brain and the distant parts of the body; and it is rendered in a high degree probable, for it cannot be said to be certain, that the anterior part of the chord is the conductor of motory influences, and the posterior of sensitive impressions.

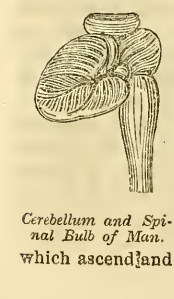
There are certain other phenomena which have their source in the chord itself. Every one is familiar with the fact, that some reptiles, when the head has been cut off, still continue to move after decapitation has been effected. Tortoises have lived weeks and months in this condition. If left to themselves, there is, after a short time, no motion, independent of external stimulus; but if a part of the body is touched with a pin or needle, or the tip of the finger, it moves;—or if the leg is drawn out and pinched, it is instantaneously retracted. These results are so common, that it is only necessary to mention them in order to bring to mind what many of you have often observed. It is important, however, because it shows that movements may take place when the brain does not exist. They do not precede a stimulus on the surface, but always follow it. It requires a sensitive impression to begin with, and then there follows a muscular contraction.

The anatomical arrangement by which this is effected will be understood by the figure (which the Professor drew on the blackboard.) If you have a section of the spinal marrow, there come off from it both kinds of filaments, motor and sensory, which unite and form a common spinal nerve. As this nerve passes into distant parts of the body, it divides into different branches, some of which go to the surface, and others to the muscles.

In the case of the decapitated reptile, when an impression is made on the skin, it is transmitted along the posterior root to the spinal marrow, but cannot go to the brain, and muscular contractions follow; but as these never result from the independent action of a nerve, the source of these contractions must be in the spinal marrow itself. The influence originating in the chord is then carried along the motor roots to the muscles. That this is the case is shown by dividing the posterior roots, and then, whatever impressions are made on the skin, no result follows from the irritation.

I have spoken of fibres passing up and down the chord to and from the brain, and which are in relation to sensation and voluntary motion. There is another series of filaments, which, instead of passing to and from the brain, pass only to and from the central portion of the chord, and these are regarded as the conductors of those influences which produce the phenomena just referred to.

PLATE CIV.



Cerebellum and Spinal Bulb of Man.

In passing from the spinal marrow towards the brain, we find that before it reaches that portion of the nervous centres, it undergoes some change in its form, becoming somewhat enlarged, forming what is called the "Spinal bulb," or Meduila Oblongata. This portion lies just within the cranium, and is usually described as a part of the brain, and consists of fibres which ascend and descend, and of the vesicular substance, which occupies the central portion, and is continuous with the same substance in the spinal marrow itself. Its enlargement or bulging is caused by an increase of the vesicular substance, which occupies the central portion, and which, by pressing out the white substance, gives it its peculiar form.

This is regarded as an independent portion of the axis, having functions quite different from the chord below, and independent of the brain above.

The nerves which are in connexion with this portion, are those which go to the organs of respiration, to the windpipe and respiratory surface of the lungs, to the organs concerned in the act of swallowing, the throat, and stomach. All the other portions of the cerebro-spinal axis may be destroyed in animals without necessarily producing death. Some animals are born without brains; the "spinal bulb" being entire, life continues for a certain period.

Flourens exhibited in the French Academy of Paris, pigeons, in which the brain was removed, and they remained standing on their feet for several weeks after this experiment had been made. The experimental Physiologists, especially Flourens, have demonstrated that in Birds and Reptiles, the brain above, and the spinal cord below the "bulb," may be removed, and yet life continue for a certain period.

The accidents which occur in the human body show that all the parts below this may be cut off, without there being necessarily any destruction of life. A person who has a fracture of the neck does not necessarily die instantly, but remains in the state of paralysis of all parts below the injury even many days, before death will ensue. These two classes of observations—those in which the brain has not existed, and the others in which the spinal chord has been cut off below, in experiment or from accident—would seem to separate this portion from all the rest, so as to enable us to distinguish the precise function of which it is the seat. Now, when thus insulated from the rest, it is able to carry on the movements of respiration, and also to influence the movements of the heart so that life may be continued. If, however, this segment is the seat of injury, death instantly follows. Injury to no other part of the nervous system is followed by such instantaneous death as injury of the spinal bulb, or Medulla Oblongata. The common practice in Europe of killing animals is by pitting, as it is called—by thrusting a knife into the Medulla—and death takes place instantly. You might thrust a knife into the brain, or into the spinal cord, and death would not be the immediate result. Instances occur in the human body, which show how necessary is the spinal bulb to the continuation of life.

Sir Charles Bell has collected instances where instantaneous death has followed injury inflicted upon it. One instance recorded by him, occurred in the Middlesex Hospital in London. A man who had fallen upon the back of his neck, after having remained in the Hospital a few days, sup-

posing that he was entirely well, was upon the point of leaving; when as he was about to say something to a friend, he turned his head without turning his body, and fell dead. On examination, it was found that there was a fracture of the bones near the base of the skull; but they had not been displaced till this unlucky accident occurred. His sudden motion of the head having displaced the fractured pieces, they came in contact with the spinal bulb, and instantaneous death followed.

Before leaving this portion of the nervous system, I shall have no opportunity more favorable to call attention to another function, of which this part is the seat in Electrical Fishes. There are four genera of Electrical Fishes, viz: the Torpedo, Gymnotus or "Electrical Eel," the Silurus Electricus and Tetraodon Electricus. The Torpedos are found in Europe, in South America, and recently a new species has been described by Dr. Storer, which is found on both sides of Cape Cod.

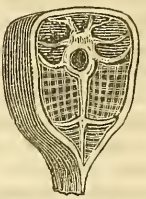
PLATE CV.

Gymnotus, or Electrical Eel.

The Electrical Eel is found only in South America. If one hand be placed on the upper and the other on the under side of a Torpedo when alive, a shock like that from an electrical machine is felt. Precisely the same result follows if the Electrical Eel be grasped with one hand by the head and with the other by the tail. The observations of European naturalists, and of Dr. Storer in this country, all go to prove, however, that direct contact with the Fish is not necessary. The Neapolitan fishermen feel the shock when they take hold of the nets, or when a bucket of water is dashed upon the Fish, the electric current passing along the threads or the fluid.

That this cause of the shock is identical with common electricity, is proved by all the tests mentioned in the last lecture. If the current from the electrical Fishes be passed through a mineral solution, by causing it to pass along a spiral wire, that solution becomes decomposed. A needle placed within the spiral instantly becomes magnetic, and if it be near a magnetic needle, the latter changes to a position more or less at right angles to the former. So that there can be no sort of doubt of the nature of the agent by which these phenomena are produced. With regard to the apparatus by which it is effected, it is made up of a series of prisms, of an hexagonal form, extending from the upper to the under surface of the body. These prisms are divided into several smaller sections, by transverse membranes running across them, forming cells. Between the prisms there exists a net-work of nerves. On passing towards the brain, to find out the source from which these nerves are derived, you find that it is from the upper portion of the spinal marrow, or spinal bulb, which is so much enlarged as to form a mass greater than the brain itself.—The electrical nerves given off from these lobes, are longer than the spinal cord itself, and are indications of the great activity of which they are the seat.

PLATE CVI.



Section of Gymnotus

The electrical organs of the Gymnotus have an arrangement somewhat different. Instead of being on the side of the head, as in the Torpedo, they occupy the space between the fins and the extremity of the tail, constituting a large portion of its whole bulk. The electrical organs are shown in the section (Plate CVI).

The fact that under the influence of the nervous system electricity is generated in a distant part of the body, has been regarded as one of the proofs that nervous influence is identical with electricity; it, however, is no more evidence of this, than that the nervous influence is identical with muscular contractility. The muscular fibre is endowed with contractility, which is brought into play under the influence of the nervous system But the contractility does not reside in the nerves.

The electrical organs have the power of generating electricity, which may be called into action under the influence of the nervous system. The latter transmits simply an influence which excites them to act, but Matteucci has shown that, when this influence is passing from the electric lobes, there are no more indications of an electric current, than when a muscle is excited to contract. The electricity is developed only in the battery of the Fish.

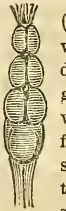
FL CVII.

Brain of Trigla or Gurnard.

In the Flying-fish, and the Trigla or Gurnard, where the fins are adapted to a kind of locomotion unusual in Fishes, there exists at that part of the spinal bulb, from which the nerves to the pectoral fins are derived, a series of ganglia (Plate CVII), which seem to be in relation to their great activity.

Passing from the spinal bulb, we come to a series of ganglionic masses, which collectively constitute the brain. Of these we can form the simplest idea by commencing at the lower extremity of the Vertebrated series and tracing it through its modifications as we ascend.

PLATE CVIII, *A*.



Brain of Conger Eel.

PLATE CVIII, *B*.

Brain of Eel, side view.

In the brain of a Fish, (Plate CVIII, *A* and *B*,) we have everything reduced to the greatest degree of simplicity. The whole consisting of the following parts:—first, a single rounded body at the termination of the spinal marrow; in front of this, two rounded

masses, the optic lobes; in front of these, is a single mass, which has received the name of Pineal Body, the functions of which are not known; in front of this, two other lobes, which give off no nerves, but, like the preceding masses, are connected with the spinal chord; lastly, the olfactory lobes in front, which give nerves to the nose. On the under side of the brain, (Plate CVIII, *B*,) there exist two rounded bodies not seen in the preceding view, and a third, the pituitary body. These different parts constitute the fundamental portions of the brain, and are repeated through all the members of the Vertebrated series.

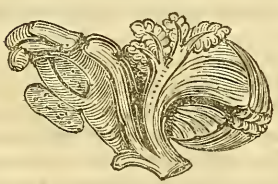
As far as the connection of the parts of the brain with the spinal marrow is made out in animals, it seems to be as follows: The fibres of the spinal chord, as they pass forwards, give off branches to each of the ganglia in succession—first to the cerebellum, then to the optic, cerebral and olfactory lobes—with regard to the other bodies, the pineal and pituitary, this connection with the chord is not made out.

In treating of the Physiology of the brain, nothing like certainty exists with regard to all the different parts; the functions of some of the parts are exactly settled, however much doubt may remain over others.

In discussing the functions of the several portions, I will commence with the posterior, and examine them in detail.

First, is the single organ, called the Cerebellum. This addition to the spinal marrow gives off no nervous fibres. It, therefore, is not a part which emanates an influence *directly* to other parts of the body. It is in connexion, however, with both kinds of fibres, which come from the spinal marrow. For some of the fibres of the anterior and posterior tracts are continued into this organ; so that whatever its function be, it must be supposed to have something to do with sensation and motion. The results which have been obtained by experimental Physiologists, and which are borne out by Comparative Anatomy, are in accordance with those obtained by Flourens, who regards the cerebellum as the centre which presides over the *co ordination* of the muscles, or that power by which a number of muscles are made to act simultaneously and for a common end, as in standing, walking, flying, all of these requiring complex muscular actions. That this view is true, the following evidence is adduced:

Plate CIX.



Cerebellum of Man (Section).

In experimenting on the cerebellum, it is uniformly found that when it has been wounded or removed, the animal at once loses his control of the necessary combination of muscular contractions to effect the ordinary movements of locomotion. If a bird thus mutilated undertakes to walk, the different parts which ordinarily cooperate, do not act together; one wing is raised while the other is depressed, and the motions of the legs are likewise deranged.

It is not, however, from experiments that the strongest proof in support of this doctrine is derived; the best evidence is derived from Comparative Anatomy—evidence, the value of which depends upon the obvious principle, that every thing in the nervous system is constructed for some special purpose; and that every organ is complex in proportion to the complexity of its function. There is always this correspondence in the animal economy, and to it there is no exception.

If it be true that the cerebellum presides over the co-ordination of the different movements of the body, we ought to find in the cerebellum a gradual increase in its complexity to correspond with the gradual advance made in the variety of muscular motions; this is borne out by actual observation of this organ in the animal series. If you compare the different races of fishes, there are some whose motions are slow, others whose motions are very active. In the Lamprey Eel, for example, which passes its time in a great measure attached to some other fish, or to some substance at the bottom of the water, the cerebellum is very simple. In the Sharks, whose activity, and whose variety of motion is the greatest in the class, the cerebellum—instead of being a simple band, as in the Lamprey, is quite long and complex—is thrown into a series of folds, (Pl. CX) to increase the amount of vesicular substance which covers its surface.

Plate CX.

Brain of Shark.

In passing to the class of Reptiles, there is but a slight variation in the complexity of this organ.—For there is but little difference in their muscular activity or in the variety of motions which they execute. Still, that there is a difference is evident; and there exists a corresponding difference between the complexity of the cerebellum and the co-ordination of motions; the Crocodile having a more perfect cerebellum than the Tortoise, and the Tortoise than the Frog, (Plate CXI, A & B).

Plate CXI. A.

Brain of Frog.

In Birds there is the same difference. If comparison be made between a gallinaccous bird, whose motions are principally those of walking, and the bird of prey, whose activity on the wing is so great, it is found that the cerebellum of the latter surpasses that of the former.

Plate CXI. B.

Brain of Frog. Side View.

Among Mammals, there exists an infinite variety in the power of combining muscular action. If the cerebellum be examined, as it exists in the Horse, or in the animals which are simply locomotive, not using their feet for seizing or retaining objects, it is found to be much more simple than it is in the Dog, or still more in the Lion, which has the power not only of using the legs in running, but of turning its wrist and of curbing the fingers so as to lay hold of objects.

And ascending still higher, the movements are found to be still more complex in the Monkey, and acquire their maximum of complication in the human body. One can hardly estimate the amount of muscular combinations which are necessary to retain the body in an upright position and perform the intricate and varied movements of the hand. And it is in man that the cerebellum acquires the highest degree of development. (Plates CIV & CIX, A and B).

So far, then, this view has a great amount of evidence in its favor. There is no other theory of the function of the cerebellum in which all the evidence conspires so satisfactorily as it does in the theory of Flourens, which regards it as a co-ordinator of motion. In order to show that it is not the seat of other functions, or at least of intellectual operations, it will only be necessary to state, that the cerebellum itself, when injured in the human body, is not necessarily attended with that disturbance of the intellectual functions which exist when other portions, especially the cerebral hemispheres, are injured.

In front of the cerebellum are two rounded bodies, called the optic lobes, and, in the higher Vertebrates, these being four in number, are called *corpora quadrigemina*, connected with the organ of vision, and about which there is no question as regards their use. These will be referred to in connection with that sense. In front of the optic lobes there is a single mass, called the Pineal body or gland, of small size in fishes, but acquiring a greater size in the higher animals. It is a body, however, the function of which is entirely unknown, but has acquired some celebrity from having been regarded by Descartes as the seat of the soul.

With regard to its structure, it consists principally of vesicular substance, and is connected with the adjoining parts by white fibres, and in the adult, almost invariably contains minute particles of sand. This sand consists of particles of phosphate of lime, and in a hundred cases it has not been found to be absent, except in a very few instances. In advance of this, are the two cerebral hemispheres, which present many points of interest, because, in them the intellect is supposed to be located. The description of these and their uses will be taken up at the beginning of the next lecture.

LECTURE XI.

In describing the brain, in the last lecture, it was found that the simplest condition in which this presents itself, is in the Fishes, where it is made up of ganglia, or lobes, superadded to the spinal marrow. The first of these is the Cerebellum; next, the Optic Lobes; in front of that, a single Pineal body, very small in Fishes, but acquiring a larger size in Mammals, though not the largest in Man: in front of this, the Cerebral Hemispheres; lastly the Olfactory Lobes.

These, with the Pituitary body and the inferior Lobes, are called the fundamental parts of the brain, because they are found in all the members of the Vertebrated series. There are other organs, however, superadded, which are, in the highest races, "organs of perfection," for the purpose of carrying on the functions of which these parts are the seat, in a more perfect manner.

The substances of which the parts of the brain are made up, are similar to those of the spinal cord; viz. the vesicular substance externally, and within, the "white substance," which is made up of fibres, like the fibres of a nerve.

The determination of the fibrous structure of the brain was a most important step; for, until this was done, nothing could be effected in the way of forming just conceptions of its Physiology; and for this, we are indebted to Gall and Spurzheim, the founders of Phrenology. They were the first to convince the Physiologists of their day, that such was the true structure of the white substance of the brain.

With regard to the relation of the different portions of the brain to the spinal cord, it was stated in the last lecture that there are filaments which pass from the latter to all the different ganglia. This is best shown in the brains of Fishes, as the superadded fibres in the human brain become so

numerous that it is almost impossible to follow them from the spinal cord into its different parts.

In examining the brains of Fishes, it will be recollected that the surface of the different lobes was perfectly smooth; except in the Shark, where the Cerebellum is represented as convoluted on the surface. In Birds, the Hemispheres are larger, but smooth, though the Cerebellum is convoluted; in the lower Mammals,the Cerebral Hemispheres are smooth, as in the Opossum; but, in the Carnivora it begins to be thrown into folds, or "convolutions;" and at last you arrive at the condition existing in the Orang and in the human brain.

It is estimated that in the human brain the vesicular portion is increased two and a half times, by being thrown into this series of folds, with a surface two and a half times as extensive.

I have described the function, as far as it can be demonstrated, of the Cerebellum,which was spoken of as the organ which presided over the co-ordination of motions, or which assisted in harmonising the action of the different muscles. This organ, in the ascending series, becomes more and more complex, as the function itself is more and more perfected. With regard to the second pair—the Optic Lobes—I have left that for future consideration, until I speak of the organs of Vision.

With regard to the Pineal body, the function is unknown. The Cerebral Hemispheres will be the next subject for demonstration. Before speaking of the functions, properly speaking, of which they are the seat, it is an important fact to be borne in mind, that, although they are the seat of the perceptive faculties, they are entirely destitute of sensibility, as is indicated by the uniform experience of the French schools of Physiologists, who have experimented on living animals, and as shown by accidents in the human body.

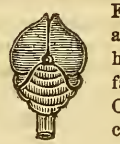
A knife introduced into the brain of an animal is followed by no signs of pain, no indications of suffering in consequence of the infliction of this injury; and accidents have occurred to the human brain without there being any indication of pain, when the substance of the Hemispheres has been cut or lacerated. The best argument, however, which can be derived in favor of this view, is, that obtained from Comparative Anatomy.

In studying the Cerebral Hemispheres in relation to intelligence, there has been a general tendency among Physiologists to locate it in them, in consequence of the injuries to this part generally being complicated with disturbances of the mind.—We know perfectly well that intelligence is the least in the lowest Vertebrate, and in the highest, is at its maximum. If there be any truth in the proposition that an organ is developed in proportion to the perfection of its function, we ought to find that the Hemispheres, or Cerebral Lobes,are increased as we ascend the series, and it will be only necessary to cast your eyes along these diagrams, to be convinced, that as you ascend in the scale, these parts gradually increase in development and acquire their maximum of development in the human body.

In passing once more to the lower portions of the series, you have but very slight variations between the Cerebral Hemispheres and the other Lobes, as in the Eel (Plate CVIII, A and B.)

In the Sharks, however, (Plate CX) which are far more active, and manifest more intelligence in the pursuit of their prey, the cerebral hemispheres are larger than in any of the Fishes.

PLATE CXII, A. PLATE CXII, B.



Brain of Bird.

In passing from the Fishes to Birds we have a manifest advance; the hemispheres being so far increased, that the Optic Lobes are in part covered by them.

The Olfactory Lobes are the next in order; but as they may be considered in connection with the sense of smell, I will not refer to them now.

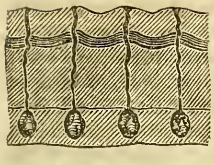
Brain of Bird.

Having completed a survey of the various parts of which the brain is made up, we have next in order, the consideration of those organs which make us acquainted with the material world around us, which transmit to the nervous centres and to the mind the impressions which give us a knowledge of the properties of matter, which give us our ideas of form, taste, odor and motion.—In the higher animals there are organs espccially set apart for the purpose of communicating these properties to the nervous centres and to the mind; some organs which are capable of giving us limited knowledge, as the eye, of light; or the nose, of odors; the ear, of sounds. But the skin is capable of giving us a greater amount of knowledge than any of the others, and occasionally taking the place of nearly all of them. It makes us acquainted with density, with temperature, with form, with movements. It may also, to a certain extent, give us an idea of distance. It seems reasonable to suppose that the sensations of sound and taste are but little else than modifications of the sense of touch; but of this I will speak hereafter. The senses of vision and smell, depend for their excitement upon an ethereal agent wholly imponderable.

The sense of touch being the most universally diffused and the most important of the senses, presents itself with its organ, first, for consideration.

In examining the skin with reference to its structure, compared with that of mucous membranes, I have already referred in part to the fact that in higher animals it consists of a series of layers, which have been variously described; but in a correct division, the skin may be regarded as consisting of two layers, (Plate CXIII) the true skin and the cuticle.

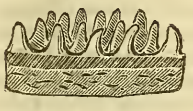
PLATE CXIII.



Section of Skin.

Connected with the skin there is a series of glandular bodies, which I have partially introduced before, anticipating the subject in another connection, whose function is to separate from the blood its superfluous moisture. In the back of the neck, where they are the least numerous, there are about four hundred to the square inch; and on the palm of the hand, where they are the most abundant, there are more than two thousand. These glands are situated just below the skin and communicate with the surface by little tubes, and opening there by orifices which are visible on the tips of the fingers and on various other parts of the body.

PLATE CXIV.



Papillæ of Skin.

The surface of the true skin is the part which is the seat of sensibility, and in the most sensitive portions is provided with appendages, in the form of papillæ, (Plate CXIV) each of which is provided with a series of nervous loops.

PLATE CXV.

Cuticle.

The skin has still another element, viz., the cuticle, (Plate CXV) which is made up of nucleated cells in different stages of desiccation or drying. Those nearest the skin are rounded, and as you approach the surface they lose by evaporation the fluid which they contain, and are gradually converted into scales or "scarf skin." Between the two, has been described a third layer, the existence of which may be regarded as very doubtful.

The more recent observations go to prove, most satisfactorily, that the difference in the structure of the skin, in the colored and white races, is not in the number of elements which enter into the formation of the skin, but is dependent upon the deposite of a pigment in the interior of the cells: the coloring matter exists in the form of little granules, not unlike the deposite of chlorophyle in the interior of the cells of plants. That there is no material difference between the two, is also shown by the fact, which is not by any means unknown, of the gradual absorption and disappearance in the colored races, of the pigment from the cells, when they assume precisely the appearance which exists in the white races.

Besides the skin, and the cuticle which invests it, there are other bodies which are appended to it, in the form of hairs, scales, feathers, &c.

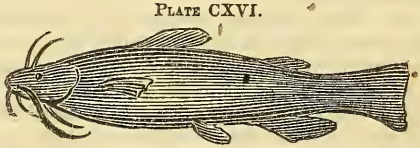
As to the sense of touch, of which the skin is the seat, this presents itself in a great variety of conditions. In the Hydra or Medusa, the whole surface seems to be equally sensitive: if any part in the Hydra be more sensitive than another, it is probably the extremity of the tentacles. As you ascend the series, particular surfaces are set aside for the especial purpose of sensation.

In the Insects, the surface of the body being covered with an insensible shell, there are certain parts whose function it is to transmit sensitive impressions. The antennæ of most insects are such organs, and are used as tactile organs, as in the common Cricket, and especially in the Ichneumon Fly, which touches almost everything with the tip of the antennæ, these seeming to guide it in its motions quite as much as the sense of vision. The Ants are provided with antennæ, which they use most incessantly, touching the surfaces over which they pass, and when they meet, seeming to make some communication with each other.

But the antennæ of Insects have undoubtedly other functions than to serve as the seat of touch. They are formed, in many instances, so that they are incapacitated from thus serving; as in some Insects, where they are provided with a series of leaves, which are arranged parallel, like the leaves of a book, but are never used to touch objects, the impression made through them being only transmitted through the air.

Among Fishes the skin is generally covered with scales, and there are but few instances where a part is organized for receiving tactile impressions. In the Siluroid Fishes there are long filaments (Plate CXVII) attached to the lips and the angles of the mouth, each provided with a branch of a nerve.

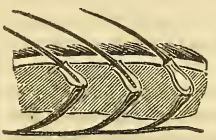
PLATE CXVI.



Siluroid Fish

In Reptiles, the surface is not peculiarly sensitive. In Frogs, where the skin is soft and yielding, the sensibility is quite acute.

PLATE CXVII.



Bristles with Sensitive Nerve

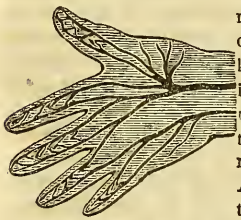
In Mammals, most of which are covered with hair, the sense of touch is most perfectly developed in those parts which are most uncovered and are brought in contact with the substances on which they feed. The sensibility of the lips of the Horse is very great, and many of the Carnivora are provided with "vibrissers" or whiskers, each of which at its root is in contact with a filament of nerve, as in Plate CXVI.

In the higher animals there exists almost every variety of sensitive surface, especially as localized in the hand or its analagous parts. The fore foot of the Horse serves simply for support and locomotion, and covered with its hoof, is the seat of the

lowest kind of sensibility. In the Dog it is not only locomotive, but it is, to a certain extent, tactile, and is endowed with a certain power of holding objects. In the Lion, the motions of the hand become much more free. It is not only locomotive, but it is prehensile, as well as tactile. In the Bear it is not only locomotive, prehensile and tactile, but the two hands can be placed in opposition to each other.

In the Monkies, the hand becomes more like the human hand. The cuticle on the surface is thinner than in the quadrupeds, and the sense of touch is more acute. The human hand ceases to be a locomotive organ, serving only for prehension and touch. For to be a locomotive organ, it must rest on the ground, and support more or less the weight of the body, also have a cuticle which shall be sufficiently thick to protect it; and this would necessarily interfere with its sensibility. Whereas in the human hand you have the cuticle quite thin; and not only this, but the nerves, which are the seat of the sense of touch, are more abundantly developed than in the Monkies or in the lower animals, especially in the tips of the fingers; but there all the skin is more or less sensitive And it has been a matter of interest to ascertain how the tips of the fingers will compare in sensitiveness with other parts of the body.

PLATE CXVIII.



Nerves of Hand.

Prof. Weber, a German Physiologist, has studied this subject, and given the result, after testing the comparative sensibility of different parts of the skin. Using, as a test, a pair of dividers, he ascertained, in the first place, what was the smallest distance which the ends could be separated and recognized as two distinct points. He found that for the tips of the fingers the least distance was one-third of a line. The tip of the middle finger was found to be the most sensitive portion where there could be recognized two points at the smallest distance. Next to this, the point of the tongue was most sensitive, where two impressions could be perceived when the points of the compasses were separated half a line. On the mucous surface of the lips two lines were necessary, on the tip of the nose three lines, on the palms of the hands five lines, on the lower part of the forehead ten lines, any thing less than ten lines gave but a single impression on this part of the skin; on the back of the hand fourteen lines, on the back of the foot eighteen lines, and on the middle of the leg, the middle of the arm, and on the back, the distance of thirty lines was necessary. In those places the compasses separated over two inches from each other resulted in a single perception.

Besides the sensibility of the skin, there is another source of ascertaining some of the properties of bodies, which is allied to the sense of touch. That is what is called the muscular sense, by which we estimate the weight of bodies. Weight is estimated by the muscular force necessary to resist the attraction of a body by the earth. Whenever an impression is simply made upon the hand by a substance resting upon it, we cannot form an idea of its weight as well as when it is supported by the muscles. A person placing his hand on the table, resting on its back, a weight of 32 ounces was placed in it. 8 ounces were added, or in some instances 12 ounces; but the person in whose hand it was placed being blindfold, was not conscious of the addition of more weight unless it amounted to eight, and in some instances, twelve ounces. If, however, the hand was sustained by the muscles, then the addition of 1 1 2 to 2 ounces was readily detected.

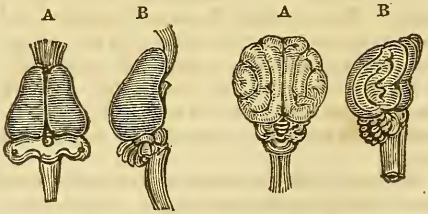
PLATE CXIX.

Brain of the Opossum.

In the Mammals, we have the simplest brain in the Marsupials; in some respects more simple than in the bird. In the Opossum, for example, the Optic Lobes are quite uncovered, (as Plate CXIX.) In the Rodentia, as for example, in the Hare, (Plate CXX, A and B,) the lobes are still smooth. In looking at the brain from above in the Carnivora you will find that the Olfactory Lobes are covered up in front, and the Optic Lobes are covered up behind, and the surface of the Hemispheres convoluted, (Plate CXX,) and in passing to the Orangs, (Plate CXXII,) the Cerebral Hemispheres have acquired such an increased size as to cover up all the other parts, except a portion of the Cerebellum, which is still visible behind. In the Human brain, (Plate CXXIII) no other part is visible but the Cerebrum itself.

PLATE CXX. PLATE CXXI.

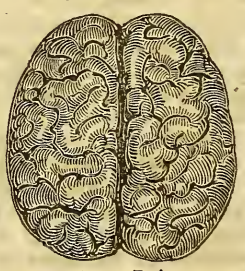
A B A B



Brain of Hare. *Brain of Cat.*

PLATE CXXII. PLATE CXXIII.

Brain of Orang.



Human Brain.

In comparing the brain of man with that of the Orang, and that of the carnivorous animal, we find a constant advance in the condition of the convolutions on the foldings of the brain. In the Cat they are arranged quite symmetrically, on the two sides.

In the Orang the cerebral convolutions for the most part, lose their symmetry. But if you compare the two sides of the human brain, no trace of symmetry remains. There are some general points of resemblance; but if you compare the opposite sides you will hardly find any two corresponding square inches that are precisely alike.

Here then, as far as comparative Anatomy goes, there exists a gradual advance from the fish to man, in the structure of the hemispheres, these parts acquiring their maximum of developement in the human brain.

It is interesting, in watching the development of the brain of the higher animals, to notice the fact, that they pass through forms somewhat analogous to those met with in the lower races. The brain of a Mammal, for example, first presents itself under a series of bodies of nearly equal size, but which are not all arranged precisely in the same line; there is a body in front, which corresponds with the olfactory lobes; then the hemispheres; then the optic lobes; then the cerebellum, and, finally, the spinal cord, which presents a cylindrical form, diminishing in size towards the posterior part.—There is a condition still earlier than this, when the nervous axis consists of a spinal cord alone, as in the Amphioxus; but subsequently, in the anterior part, there is a series of bulgings or vesicles, which are transformed into the fundamental parts of the brain. Then other parts are superadded, which give it the complexity which it has in the different races and in the human brain. Thus we have the brains of the higher animals in their phases of development, corresponding to the permanent condition of the same parts, in the lower members of the series.

If the cerebral hemispheres be the seat of intelligence, we ought to have an argument not only from comparative anatomy of the brains of animals, but from the comparison of the brains of human beings The extreme differences which exist in the human races, however, are far less than the differences which exist between man and the races Immediately below him in the animal scale. Nevertheless, in comparing the brains of the human races with each other, or of individuals of the same race with each other, there has been ascertained to exist a very considerable range.

In order to establish correct comparisons, it is necessary to ascertain first what would be the average size of the brain. This can only be ascertained by measuring in various ways large numbers of brains. This has been done by several physiologists, especially by Dr. Reid of Edinburgh, who gives the average weight of an ordinary human brain, as obtained by weighing fifty-three brains of males, three pounds, two ounces, three and a half drachms.

We have now to compare, as far as practicable, this average weight of ordinary brains with that of persons, on the one hand, who have been remarkable as men of genius, and as possessing the highest order of intellect, and with those, on the other hand, who are at the opposite extreme, possessing the least amount of intelligence, as is the case in idiots, which would form the lowest limit of the scale. With regard to the brains of men of the highest order of intellect, there are but very few instances on record where they have been weighed. But the size of the heads of such persons is a sufficient index to show that their brains far surpassed the average size of those who are not in any way remarkable for superiority above their fellows. We have abundant evidence of the correctness of this in the heads of Michael Angelo, Galileo, Bacon, Newton, Shakspeare, Napoleon, Cuvier, La Place, Humboldt.

The largest brains, whose weight has been accurately determined, are those of Dupuytren's, a French surgeon, and Cuvier, the former not generally known except in the professional world, but with all those peculiarities which entitle him to a consideration among men of great intellect, had a brain which weighed four pounds and ten ounces The brain of Cuvier, one of the most distinguished men in modern times for powers of analysis, method, and capacity for grasping the natural sciences had the largest brain, which has been accurately ascertained, weighing four pounds, eleven ounces, four drams, and thirty-six grains. Other brains have been recorded as exceeding this. Among them those of Lord Byron and Oliver Cromwell But from the excessive weight which has been ascribed to them, the record must be incorrect. The weight of Oliver Cromwell's brain was given as six pounds; more than one pound heavier than that of Cuvier. Soemmering had an opportunity of examining the skull of Oliver Cromwell, but was not struck with its size being so much above that of an ordinary head, as this would indicate. Byron's head gives no indication that it would have served to lodge a brain so large as it is stated to have held, viz.: one weighing also six pounds. These two instances cannot, therefore, be received except with doubt.

Let us pass next to the other side of the scale. Tiedemann has given the weight of the brains of idiots which fell under his observation, as follows: in one 50 years old, the weight was one pound eight ounces and four drams. In another, one pound eleven ounces and four drams. In another, 40 years old, one pound six ounces.

Here, then, you have the average brain weighing three pounds and 2 ounces, the highest four pounds and eleven ounces, and the lowest, the idiots, not any of them, two pounds in weight. It is not to be inferred that *all* idiots have small brains, though it is quite true that excessively small brains are unerring indications of feeble intellect. The brain

may have its average size, but either badly organized, or from some other cause rendered incapable of acting.

In comparing the brains of different individuals, it has been noticed that there is a great difference, not only in the number of the convolutions of the surface, but also in the depth with which they are folded in.

It was noticed in Cuvier's brain, that the vesicular portion was in much larger proportion to the white substance than was usual. In the Comparative Anatomy of the brain, it would appear, that as you descend in the scale, not only do the surfaces of the hemispheres become smooth from the disappearance of the convolutions, but the vesicular substance becomes thinner.

In comparing the brains of the different human races, there is shown to exist some difference; though two extremes in the human race do not vary more than five cubic inches. Dr. Morton, of Philadelphia, who has the largest collection of National Crania in the world, nearly one thousand in number, has measured the capacity of them all with great accuracy, and has spared no pains to render his mode of measurement as correct as possible. He gives as the result of his investigations, that the Caucasian brain, as indicated by the capacity of the skull, is the highest in rank, especially the German and Anglo-Saxon, which has an average capacity of ninety cubic inches. The maximum Caucasian had a capacity of one hundred and thirteen.

Measuring the capacity of the brains of forty-six native Africans, he found that the average was 85 inches, five cubic inches, less than the Caucasian; and between the two, came the other human races —namely, the Mongolian, the Malays, and the North American Indian. The North American Indian coming next to the African, and above these, the Mongolian, and the Malays coming next to the Caucasian.

I have already referred to the fact that the Cerebral Lobes, or Hemispheres, were double—an important fact to bear in mind in connection with the explanation of the continued healthy condition of the mind when a portion of the brain has been destroyed. There are abundance of instances in which one side of the brain has been injured—where a portion of the brain has been removed; and this has not interfered permanently with the intellectual operations of the individual. Not only this, but there are instances on record where a whole Hemisphere has become disorganized, and the operations of the mind carried on with their usual activity.

Sir Charles Bell gives an instance which fell under his observation, in a person who was epileptic, and from the time she was six years old had paralysis of one side of the body. Her "senses," however, were preserved, and her intelligence was regarded by her associates as good and active. Dying ultimately of disease of the lungs, an examination was made with reference to ascertaining the cause of the paralysis. The Hemisphere on the right side was found to be one-fourth of its natural size, consisting of a sac filled with fluid, also surrounded by a fluid which occupied the space between it and the skull. Other instances are on record.

If, however, both Hemispheres be diseased, there is almost invariably a disturbance of the intellect.

The most probable explanation of these facts is, that Hemispheres being double, one may replace the other. There are two optic lobes, and there are two Olfactory Lobes, which are known to act independently of each other, and there does not appear to be any strong *a priori* objection to the same holding true of the Cerebral Hemispheres.

LECTURE XII.

At the close of the last lecture, I described the structure of the skin, as the seat of the sense of touch. This was shown to consist of two elements: an internal portion, highly organized, and an external, having a low degree of organization, and serving as the protecting organ of the more delicate part within. The internal portion, highly vascular, is supplied with a large number of nerves, where the sense of touch is strongly developed; also with secreting glands and ducts.

The next organ of sense that will be described, and which may be regarded as a modification of the sense of touch is that of taste, having its seat in the mucous membrane of the tongue. As has been stated, if the skin be followed over the lips into the mouth, it is found to be continuous with the mucous membrane of the mouth, and passes over the tongue; thus it is continuous with the covering with which that organ is invested; and on examination, it will be found to consist of the same elements of which the skin is made up, only the papillæ are in the tongue far more highly organized than on the general surface of the body.

The papillæ of the tongue are of three kinds; one existing at the base of the tongue, another

scattered over the general surface and on the sides, and another series, still smaller and more numerous. The first of these are conical; the second enlarged and flattened at the top; and the others have the same form as the preceding ones, but instead of rising above the surface, are imbedded in it. These last are few in number, and are situated at the base of the tongue, and are arranged in the form of a triangle, as shown in Plate CXXIV. Each papilla is provided with a series of nervous loops, and covered with cuticle.

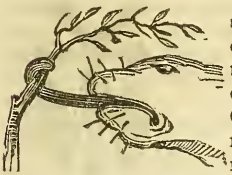
PLATE CXXIV.

Nerves of papillæ of Tongue.

As far as the elements of the tissue in which the sense of taste is seated are concerned, they are precisely similar to the skin, excepting that the papillæ, are at the maximum of development. In order that this sense may exist in a state of activity, it is necessary that the substance which is to act upon it should be in a state of solution; for if the substances be insoluble, or if the tongue be dry, no impression is felt but that of common touch.

The tongue, besides subserving the sense of taste, in a few instances subserves an entirely different purpose; and it is an interesting fact to look over the animal series and see how far nature deviates from a particular plan, so that there are organs having a particular purpose, and in a vast majority of instances fufilling purposes entirely different.

PLATE CXXV.



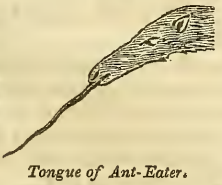
Tongue of the Giraffe.

The tongue sometimes subserves an entirely different purpose from that of taste. The tongue of the Giraffe (Plate CXXV), forms a long flexible organ, which almost takes the place of a hand, and by which small bodies may be taken up with ease; it also serves for the purpose of stripping the leaves from the trees on which it feeds.

PLATE CXXVI.

Tongue of Chameleon.

PLATE CXXVII.



Tongue of Ant-Eater.

In some Reptiles, and more especially in the Chameleon (Plate CXXVI), the tongue serves the purpose of securing the Insects on which the animal subsists. It is enlarged at its extremity, secreting a viscid fluid, and when projected against Insects, they readily adhere to it.

The tongue of the Ant Eater (Plate CXXVII), like that of the Chameleon, is covered with a viscid secretion which serves to cause Insects to adhere to its surface.

PLATE CXXVIII.

Tongue of Woodpecker.

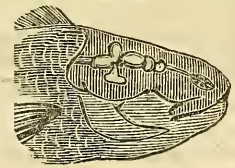
The tongue of the Woodpecker (Plate CXXVIII), forms a sort of spear, with barbs on its upper edge, with which it transfixes Insects and grubs on which it feeds. There are two muscles; one is attached to the bill in front and passes around from the top of the tongue over the top of the skin; when that contracts the tongue is protruded when the other muscle contracts, the tongue is drawn in.

The sense of smell is not known to exist in all the members of the animal series.

There can be no doubt but that many Invertebrate animals are capable of perceiving odors, although there is no organ of smell which can be detected. If it exists, it is doubtless at the entrance of the respiratory orifice, where the air passes in and out.

In Vertebrated animals, the organ of smell exists in two principal forms: a sac, containing within it a folded membrane, each fold of which is provided with a large supply of nervous filaments; and a canal, opening into the mouth at its posterior part, and through which the air passes during the process of respiration. We have an illustration of the first form in a Fish (Plate CXXIX), and of the second in the Human Body (Plate CXXX), which type also exists in Reptiles, Birds and Mammals.

PLATE CXXIX.



Brain and Organ of Smell in a Perch.

PLATE CXXX.

Organ of Smell in Man.

Physiologists consider there can be no question as to the precise centre which presides over this sense—that is the first pair of ganglia, at the anterior part of the brain, the Olfactory Lobes.

In the human brain, these Lobes are not so readily detected, because they are proportionally so much smaller than the Cerebral Hemispheres. In the Kangaroo, they are much more perfectly developed than in Man. And indeed in Man, they are far inferior to what they are in many animals quite low in the scale. We can judge of this, not only by the size of the ganglia, but also by the size of the cavity which contains the brain, as compared with the cavity which contains the organ of smell. If you compare the human skull with that of the Antelope, the Deer, and others, you will find the cavity which lodges the brain to be very small in the latter, and that which is the seat of

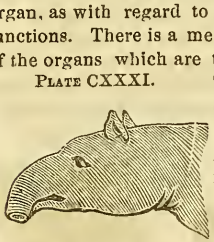
the sense of smell to be several times larger; a very different state of things from what exists in the human head. Judging, then, merely from the size of the organ, we should be justified in saying that it exists in a far higher condition in many animals than it is in the human body

The organ seems to be more perfectly developed in the Carnivorous and Ruminant animals than in any other members of the series. Birds are said to have this sense very acute, but it is far more probable that they principally depend upon the sense of sight.

It has been supposed that the Vultures, who have the power of perceiving the carcasses on which they feed from a great distance, find them by the sense of smell. Mr. Audubon found that an animal, dead for several days, covered up by bushes so that it could not be seen, but was not noticed by the Vultures. They sailed around at a great distance, but did not seem to be aware of its presence. Yet in another case, where the skin was placed in an open space, stuffed and dried, so that no odor came from it, that was at once noticed. They came at once to the stuffed skin emitting no odor, when they would pass the carcass unnoticed, though giving them the strongest indication of its presence through the sense of smell.

The same remark holds good with regard to this organ, as with regard to those performing other functions. There is a metamorphosis in the form of the organs which are the seat of this sense.—

PLATE CXXXI.



Tapir.

There is here a rudiment of the trunk in the Tapir. In the Elephant you have the nostrils so far prolonged as to serve the same purpose as the tongue of the Giraffe, or even of a hand for it. It is a prehensile organ—The Bats of South America are provided with an external appendage to the nose, doubtless the seat of the sense of touch. At least that is the inference; for the nerve connected with it is distributed to the skin of the face.

The next organ of sense, and one of the most complicated of the series, is that which is subservient to the sense of hearing. The Auditory apparatus is constructed for the purpose of conveying impressions derived from the vibrations of the air or water by which an animal is surrounded, to the Auditory nerve. The lower limit of the animal series, where an Auditory apparatus is found, is not easy to determine. In the Vertebrated series there can be no difficulty; for you can trace the organ by regular gradations, from the most to the least complex. Yet as you pass to the Invertebrated series, it becomes almost impossible to determine whether an organ is adapted to be the seat of this sense, because you have not the analogy of structure to guide you.

At the base of the antennæ, there is, in the Lobster, (Plate CXXXII), a projection covered with an

PLATE CXXXII.

Ear of Lobster.

PLATE CXXXIII.

Termination of Auditory Nerve, in loops

elastic membrane and sac, on the walls of which are found the branches of a nerve.

The simplest organ of hearing which is known to exist in the Vertebrated series, is a sac, with a semi-circular canal opening into it. Passing into this sac, which is filled with fluid, there are filaments of nerves, some of which go to the commencement of the canal, (Plate CXXXIII), and others to the centre of the sac, in contact with particles of calcareous matter in the form of fine powder.

You have an addition of parts as you ascend in the series. In the Lampreys, you have two semicircular canals, and in all the higher Fishes there are three. In the higher animals these parts are repeated and others superadded.

Here you have, in (Plate CXXXIV) the sac, five openings into the cavity, two of the canals com-

PLATE CXXXIV.

Ear of the Augler.

PLATE CXXXV.

Brain of Shark, with the Organs of Sense, Eye, Ear, and Olfactory Lobes and Nerves attached.

municating together. The Auditory nerve arises from the side of the spinal bulb, (Plate CXXXV) but is not provided with a distinct ganglion or Lobe, like the nerve of the eye and the nose.

As you descend in the series, in the class of Reptiles, there is superadded another portion of the apparatus, which is repeated in the Birds as well as in the Quadrupeds; and that is, an addition to the sac—the cochlea—which is provided with an-

PLATE CXXXVI.

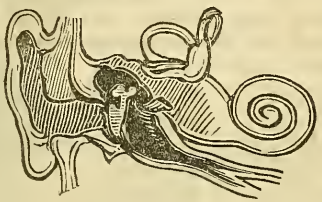
Ear of a Bird.

other series of nervous filaments. There is, in addition to this, a vibrating membrane, (Plate CXXXVI), or membrane of the tympanum, and a bone, "columella," which makes communication

with this vibrating membrane and a fluid contained in the interior of the sac.

In the Quadrupeds and in all the Mammals, you have it somewhat more complex, but constructed in the main precisely on the same plan as in the human body. In the central portion, (Plate CXXXVII,) you have a part corresponding

PLATE CXXXVII.



Human Ear.

to the sac. Behind that there is a portion coiled up in a spiral form, which is only the cochlea more completely developed; and more externally there is the cavity of the tympanum, a series of bones (Plate CXXXVIII) instead of the columella, an external auditory canal and external ear.

PLATE CXXXVIII.

Bones of the Ear.

In one of the first lectures, I referred to the gradual disappearance of these parts in the animal series. If you examine the ears of the lower Mammals, you find that the external ear has disappeared; in Birds, not only this, but also a portion of the external canal; in Reptiles, you come to the vibratory apparatus, where it is on the surface; in Fishes, the vibrating membrane has disappeared, and with it the cavity of the tympanum and the cochlea, and nothing is left but the internal apparatus.

The uses of the parts of the ear may be easily enough understood by a reference to the common principles of Physics. In Fishes, (Plate CXXXIV) you have the sac filled with fluid, and in that fluid floating the filaments of the nerve.

The vibrations of the water are communicated to the skin, then to the fluid, and finally to the nerves themselves. Vibrations are carried with great intensity through fluids. If two bodies be struck together under the water, while the head is beneath the surface, the slightest blow made by them will be transmitted through a great distance.

If the animal live in the air, an entirely different structure is necessary, because vibrations in the air are not transmitted with any degree of intensity to fluids. If the ear be below the surface, and any noise be made in the air, it is transmitted through the water with but little intensity. Now, how is the vibration in the air to be transmitted to the fluid in the cavity of the ear? This is effected by the parts which are superadded in those animals living above the surface of the water. The vibrations of the air which are not easily transmitted to the water, are very easily transmitted to a tense membrane. If a musical instrument be played over a tense membrane, as a drum head, it is instantly thrown into vibrations. as will be found by placing grains of sand upon it, which will move as the drum head vibrates. It is the same with the membrane of the ear, which will be excited by the most delicate sounds.

The next point is to ascertain how the vibrations of this membrane can be transferred to the fluid. That is effected by the addition, in Reptiles and Birds, of a little bone, one end of which touches the vibrating membrane, and the other rests upon the auditory sac. The impression is made from the membrane upon the little bone, or columella, and thence to the fluid within, and finally to the nerves.

In Mammals there exists a series of bones, which are so arranged (Plate CXXXVIII,) that they turn on two centres. One of the arms or processes is lodged in an opening at the side of the cavity of the tympanum; another is attached to the opposite side; a third is attached to the under surface of the vibrating membrane. So that when the membrane vibrates, the bones are carried backwards and forwards, turning on the arms as on pivots. The only difference in this form is, that the bone, which makes an impression upon the capsule within, is at the extremity of the lever, instead of being directly at the end of a straight bone moving in the direction of its axis, as in the Birds and Reptiles. The cavity of the tympanum which is represented, is intended for the purpose of allowing the membrane to vibrate freely air existing on both sides. Being tense, it is thus precisely in the condition of a drumhead, and the intensity of its vibration will be in proportion to its tension. In a drum, in order to have the vibrations produced in their greatest intensity, there must be an opening or "vent," so that the air may pass in and out, offering no obstacle to the movement of the membrane.

Precisely the same condition exists in the mechanism of the ear. There is a tube between the cavity of the tympanum and the mouth, called the Eustachian tube, which enables the pressure to be equalized by the entrance and exit of air, as the case may require. That this is important is shown by the condition of the ear when this tube is closed. The tympanum no longer vibrates freely, and hearing is much less perfect. You find proof of its importance in the experience of those who have descended in diving bells to a considerable distance below the surface of the water or into deep mines.

As the diver descends, he soon experiences a ringing in the ears, which constantly increases as the air on the outside of the tympanum becomes more dense. This is readily relieved by forcing air through the Eustachian tubes into the cavity of the tympanum, and thus equalizing the density

on the two sides. If the density on the outside be the greatest, the tympanic membrane is bent inwards, and the bones in connection with it press more forcibly on the fluid of the sac in contact with the nerve.

The use of the external portion of the ear has been a subject of much discussion, and it is not yet perfectly determined, especially in the human body. In many of the lower animals its form is such that it collects sounds, and transfers them to the vibrating membrane.

But the human ear is so formed that it could not act in this way, for if sounds be reflected from it, they would not be directed, when striking its outer portion, to the Auditory canal. There is ground, however, for the belief—as the experiments of Savart show—that it not only acts as a reflector, but as a conductor, and this last in virtue of the elasticity derived from the cartilage.

In passing to the last organ of special sense, we have the eye, which may be regarded as the most delicate and the most complex of the whole. The lower limit of the organ of vision in the series is as difficult to ascertain as that of hearing. In passing through the Vertebrated Animals, structural analogy guides you with certainty.

But as you pass to the lower members of the series, much doubt exists. The simplest eye, it is propable, merely gives the idea of light. And something of this kind of sensibility may be said to be diffused over the whole surface of some of the lower animals. The Hydra will change its position constantly, so as to secure the largest amount of light. If placed in a vessel partly shaded, it will always approach and remain in the lightest part. But there is no one part of the surface which may be said to be more sensible to light than another.

In Planaria, certain "eye dots" exist on the sur-
Pl. CXXXIX. face, about the head, each one of these provided with a filament of a nerve (Plate CXXXIX). It cannot be shown clearly that these are organs of vision, but they seem to fall into the series so regularly after the more complex forms that have been described, that we are warranted in regarding them as the analogues, at least, of eyes.

Planaria.

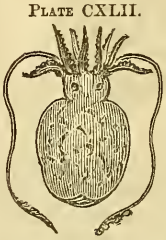
Among Mollusks, eyes are presented under a
Plate CXL. great variety of forms. In Pleurobranchus (Plate CXL) there are two eyes, on the upper part of the head, having the structure of the veritable eye; that is to say, they are provided with refractive media, which serve to concentrate the light, if they do not go so far as to form a distinct image. The eyes are incapable of any motion, except as the head moves.

Pleurobranchus.

In the animal of the porcelain shell, the eyes are placed at the base of the tentacle, so that they can move as it moves. In other Mollusks, as in the
Plate CXLI. animal of the cone shell, it is situated quite near to the tip; and in the Achatina (Plate CXLI) just at the tip, where it enjoys the greatest possible degree of mobility. In all of these instances, the eye itself is not moveable, but the tentacle to which it is attached moves.

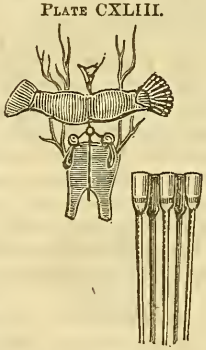
Achatina.

Plate CXLII. Passing to the Nautilus and Cuttle-fish, the highest of the Mollusks, Nature seems at first sight to have receded; for the eye is again situated on the side of the head.—(Plate CXLII). This eye, however, is endowed with a property which none of the preceding instances exhibited; it is capable of being moved, as in the higher animals and in man, independently of the parts by which it is surrounded.



Cuttle fish.

Among Insects, (Plate CXLIII) the eye assumes
Plate CXLIII. the most complex form which it does among the whole animal series. You have the individual parts themselves quite simple, but the number which make up the eye is very great, amounting in some instances to several thousands. Each eye is made up on the surface of a series of tubes, lined within by a coating of black pigment. There is a nervous expansion only at the inner end. These are so arranged, that although there be no lens—nothing to concentrate the rays of light by refraction, so as to form distinct images—yet, by the aid of the tubes, all the rays coming from any one part of an object are kept quite distinct from those coming from any other—as none of the rays, except those parallel to the axis of the tube, can reach the bottom so as to come in contact with the nerve.



Eye of Insect.

The eyes of all the Vertebrates are essentially after the same general plan, their principal modifications being with reference to the medium by which they are surrounded.

The nerves arising from the Optic Lobes in nearly all cases unite as in Plate CXLIV, then diverging enter their respective eyes. If the animal live in the water, the lenses, as in the Cod, (Plate CXLV,) and Fishes generally, and in the Seal among Mammals, (Plate CXLVI,) are very nearly spherical, so

PLATE CXLIV.

Optic Nerves and Globes

PLATE CXLV.

Eye of Cod.

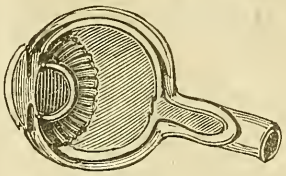
PLATE CXLVI.

Eye of Seal.

as to compensate for the similarity of the densities of the fluids within the globes, and the water, which is external.

Among other Mammals, as in Man, (Plate CXLVII,) also in Birds, as in (Plate CXLVIII), the difference between the densities of the air and the fluids within the eye is so great that a lens of large curves is all that is required.

PLATE CXLVII.



Human Eye.

PLATE CXLVIII.

Eye of Duck.

The muscles of the eyes of all Vertebrates, are six in number, four for the ordinary motions for directing the eye to different objects, and two denominated "oblique muscles," one of them passing through a pulley, and which serve to give the globe a rotatory motion on its axis.

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